COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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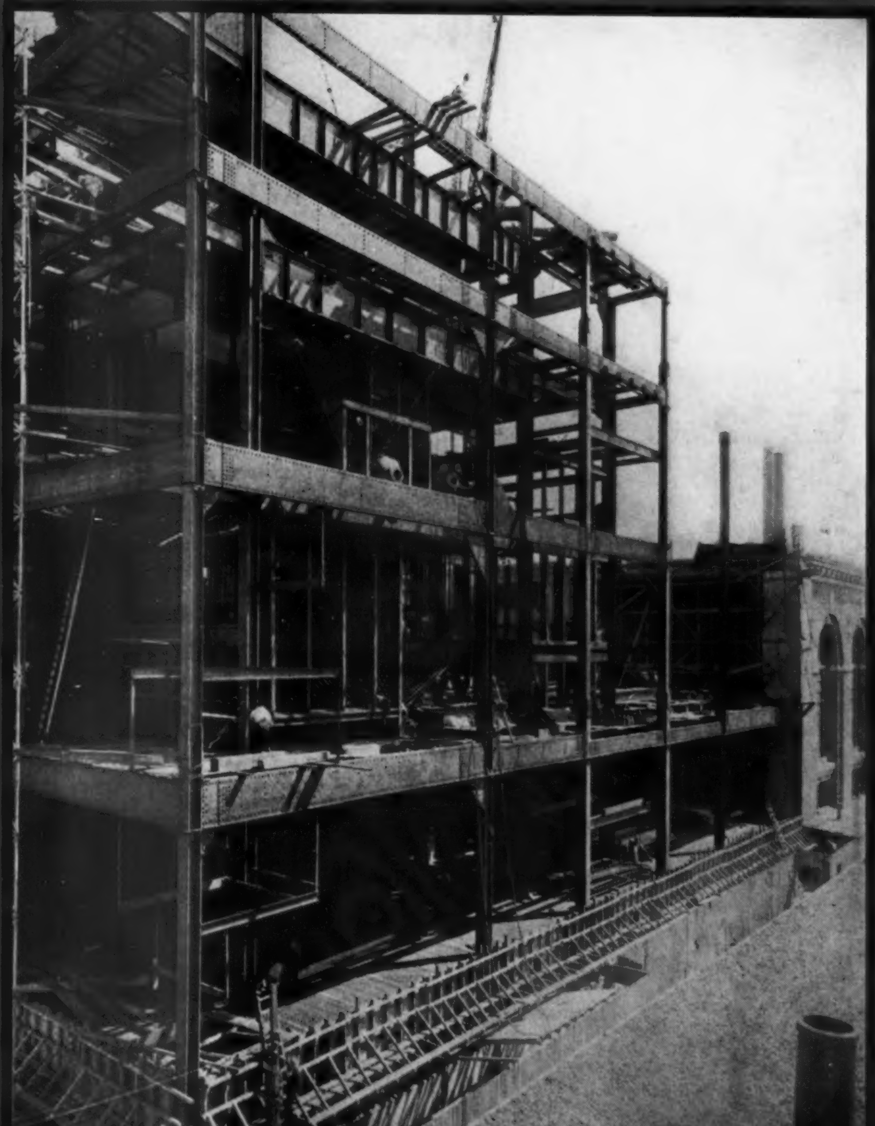

Construction view of high-pressure boilers at L Street Station, Boston

Boiler Tests at Riverside Station

New Topping Unit for L Street Station

High-Pressure, High-Temperature Valves

Relation of Characteristics of Bituminous Coals to Their Use in Pulverized Firing

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FOR NOVEMBER 1938

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EDITORIAL

Tube Failures

The October issue of *The Locomotive*, the quarterly publication of The Hartford Steam Boiler Inspection and Insurance Company, contains a most interesting discussion on tube failures in water-tube boilers which it notes still continue in considerable number. While such failures, in themselves, are seldom serious, they nevertheless are of greater import from the standpoint of outage with the modern high-capacity unit, than was the case formerly when the shutting down of one of several medium-capacity units caused less inconvenience to operating schedules.

As pointed out, tube failures may be attributed principally to inadequate circulation, improper feedwater conditioning, the presence of free oxygen and the formation of Fe_3O_4 deposits in the superheater, due to the decomposition of steam at high temperatures, such decomposition becoming relatively rapid at around 1000 F.

It is observed that the designer's problem would be simplified and results could be predicted more definitely if there were assurance that the unit would be operated under the conditions specified, but that local practices often alter the anticipated conditions with subsequent cases of tube failures. This is particularly true with reference to changes in fuel, unsuitable feedwater treatment, the presence of free oxygen and concentrations carried—all of which are beyond the control of the designer. It might have been added that, despite the vast amount of design data available and a wealth of accumulated experience, the designer is not always free to exercise his best judgment because of conditions imposed.

Stressing the importance of circulation in modern high-capacity boilers as greater amounts of water are evaporated into steam per unit of steam generating surface, the article concludes that such development "has necessitated the design and construction of boilers that are as sensitive as turbines," and that, "their successful, efficient and safe operation is dependent on proper speed of fuel to the burners, of gases through the passes of the boiler, of water from the heaters to the pumps and from the pumps to the boiler, of steam from the tubes and drums, and of steam through the superheaters and piping to the prime mover. If any element of circulation on which the rapid absorption of heat through the tube walls depends, is disturbed, burnt tubes are apt to result."

Such sensitivity is more noticeable in some types of boilers than in others and high steam pressures appear to have a very definite bearing on the circulation of boilers of the straight-tube header type, particularly with variable degrees of solid concentrations in the boiler water.

However, as one well-known engineer recently pointed out in a discussion at an engineering society meeting, many unforeseen problems were previously encountered and ultimately solved with each advance in practice and tube failures are by no means new; but one is prone to forget the earlier experiences. Today's problems are somewhat more complex because of the greater number of factors involved and the more exacting demands but their solution is imminent—hardly, however, before new problems are encountered by further advances in practice. Such is the price of a rapidly advancing art in which the ultimate gains outweigh the difficulties encountered.

Extensions to Power Capacity

Comment was made in these columns in September upon the appointment by the President of a special committee to study power supply in its relation to national defense. While no formal report has yet been issued, the daily press recently devoted considerable space to a meeting in Washington between this committee and a group of utility executives. According to a statement, following the meeting, by Assistant Secretary of War, Louis Johnson, an agreement was reached toward a two-year extension program as the initial step in building up and coordinating the nation's power resources to meet the needs of national defense. It was pointed out further by Mr. Johnson that this projected expansion would serve to prevent the dispersal of highly-trained technical staffs among companies making power plant equipment.

No detailed information was given out and, according to certain well-informed sources, generalities rather than definite commitments were discussed, although it was announced by one spokesman for the utility group that the plans for immediate expansion would involve between seven hundred thousand and a million kilowatts. This figure is small compared with the growth in pre-depression years and is slightly more than that added in 1937. It is in line with what might be expected under present conditions and if put into effect would serve to advance construction schedules.

It seems agreed, by those in a position to know the facts, that there is at present no general shortage in power capcity, despite some shortage in reserve in certain instances. However, the curve of power consumption has been steadily rising since the low point in June, has passed that of 1936 and has nearly reached the corresponding monthly value for 1937. The adequacy of present capacity to meet a marked upturn in industrial activity, particularly if augmented by orders related to national defense, is a matter upon which opinions differ and in which the Government evidently feels concern; especially in view of the time element involved.

This latest move on the part of the Federal Government may be looked upon as an attempt to stimulate activity by private initiative in the field of steam power in which pump priming has proved to be ineffectual. The issue of power for national defense appears to afford a timely approach to the problem and may possibly serve as a basis for cooperation and the establishment of goodwill between the utilities and the Government to replace the *impasse* that has existed for several years. Of course, there is no assurance that such a condition can be brought about, but it may be worth the attempt.

Developments in High-Pressure, High-Temperature Valves

By V. T. MALCOLM, Director of Research
The Chapman Valve Mfg. Co.

The author reviews the work of the last fifteen years in the development of materials and the design of valves to meet the trend toward ever increasing steam pressures and temperatures. Reference is made to the work of special committees of the A.S.T.M. and the American Engineering Standards. The results of an investigation of the efficiency of bolted joints in bonnet flanges are included and the influence of welding in present-day valve practice is discussed at length.

PROGRESS in central station design and operation has been so rapid as to bewilder sometimes even men who have given their whole time and thought to this work; for today's economic conditions, more than ever before, are imposing upon us the necessity for efficiency in every phase of industrial activity among the most important of which is the economical generation of steam.

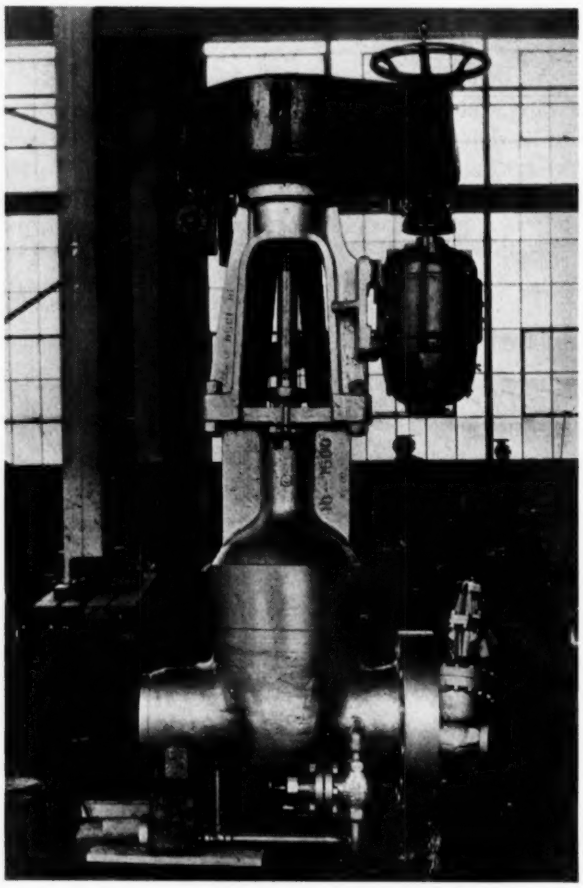
That economy may be improved by the employment of greater pressures and higher temperatures is established, but the realization of this economy is in no small way dependent upon the effective utilization of materials of construction. Higher steam temperatures are restricted to the limitations of the materials for such use.

Many more plants will be designed for and operated at 1200 to 1400 lb per sq in. pressure and 900 to 950 F total steam temperature, in addition to the considerable number already in service under such conditions. Furthermore, we have now entered the realm of the 2500 lb, 1000 F station. One approximating these conditions has already been laid down; one or more are under consideration and there is little doubt that continued progress will be made, if research and engineering continue to cooperate as in the past.

Along with the construction of major equipment, the old adage that "a chain is no stronger than its weakest link" has particular bearing on power plant practice. While valves are only a minor part of the major equipment, they nevertheless play an important part in the operation of the station. When it is considered that the outage of a unit, costing many thousands of dollars, may result from improper functioning of a valve, costing a few hundred dollars, the design and construction of valves becomes most important.

With present exacting service demands and the trend toward minimum reserve capacity, reliability in valves becomes paramount. By continued research we must emphasize the importance of design, materials and workmanship, and organizations that have the will to pioneer and the resources to carry out such pioneer work, must certainly be looked upon as progressive in the art.

The engineer engaged in central station work needs in valves a comparatively cheap alloy steel that has high physical properties, which properties are not greatly impaired by continued service at high temperature.



Ten-inch, 1500-lb, 1000-F welded-bonnet valve with bypass connection and motor unit in place

He needs, in the valve, seating materials that are resistant to high temperature gases, that will hold their surface under heavy sliding pressure, that will not suffer from seizing or erosion due to the high velocity and pressure used and at the same time have excellent resistance to corrosion and oxidation. Therefore, the metal in all parts of a valve must be stable at the temperatures employed and be capable of resisting, for the economic life of the equipment of which it forms a part, the stresses to which it will be subjected in service.

This month marks the fifteenth anniversary of the first report on the "Investigation of Materials and

Tests" made to the Sectional Committee on Pipe Flanges and Fittings of the American Engineering Standards Committee, and it is fitting at this time to point out that the problems reported upon by the special investigating committee had a great deal to do with the design, materials and construction of present-day high-pressure valves.

The problems presented to this special committee at that time were the investigation of and the advisability of conducting research into:

1. Impact tests
2. Endurance tests
3. Hardness tests
4. Magnetic tests
5. Metallographic tests
6. Short-time tests at high temperature
7. Long-duration tests at high temperature
8. Inspection by X-ray
9. New stud-bolt materials
10. Marking
11. Recrystallization of steel
12. Study of permissible and efficient design in the utilization of castings for valves
13. Advisability of new materials for valve trim such as seat rings, disks and stems
14. Manufacture of steel

The temperature comtemplated at that time was a maximum of 750 F.

When we look back over the intervening years since the original investigation, we are reminded of the remarkable strides that have been made; for most of the problems suggested at that earlier period have been solved, and from the results obtained by this investigation has developed the basis of design and materials for today's high-pressure, high-temperature valves.

In 1923 the organization with which the author is identified brought out the first alloy-steel valve for central station work and carried out the first research investigation into the manufacture of steel castings by use of the X-ray, which work was then done at the Watertown Arsenal with the cooperation of Dr. H. H. Lester.

In 1924, the Joint Research Committee on the Effect of Temperature on the Properties of Metals, and Subcommittee 22 of Al, A.S.T.M., on Materials for Valves, Flanges and Fittings were organized and have functioned in a thorough and efficient manner to date. Out of these committees have come excellent standards for materials and a vast knowledge of the effect of temperature on the properties of metals.

Of late years radiography and welding committees of the A.S.T.M. have been organized. The Sectional Committee on Pipe Flanges and Fittings of the American Standards Association has developed new valve and fitting standards up to 2500 lb pressure at 950 F, and has set forth in these standards temperature-pressure ratings for both carbon and alloy steels.

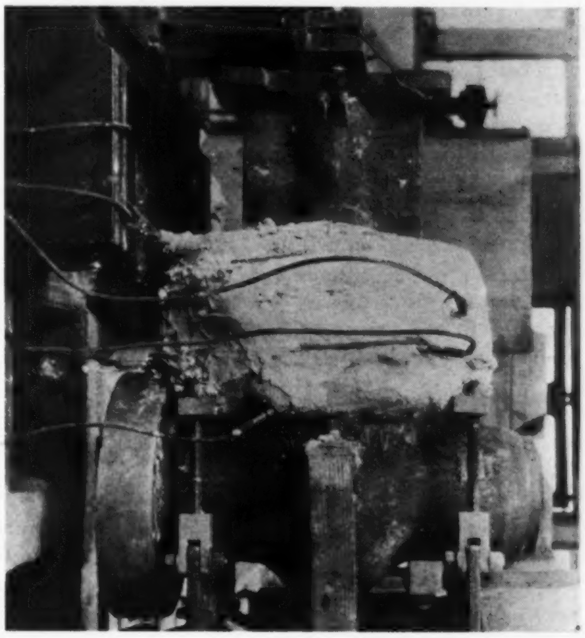
In our organization new alloy steels have been adopted for castings, forgings and stud bolts. Research has been carried on to such an extent that specifications calling for impact, hardness, creep tests, metallographic and radiographic inspection are acceptable and, as a matter of fact, all of these tests are now in use in the daily control of our products.

Great improvements have been made in heat-treating of all parts entering into valve construction and, due to radiography and metallography, marked advances have been made in casting and forging procedure.

Stud bolts are now made of exceptionally high strength steel, stable at high temperature and full-length threaded, so as to distribute the stress uniformly over the entire bolt. Nuts are made of carbon and alloy steel, quenched and drawn, and so treated that sticking of the nuts to the bolt is a thing of the past.

New types of valve trim have been adopted so that seizing, galling and erosion have been eliminated or mitigated to such an extent that they are no longer bothersome. Castings have been redesigned so that all sections are as nearly uniform as possible and heavy pads have been eliminated.

Due to the recent depression fewer stations have been constructed than would otherwise have been undertaken; but the seed of research has been planted as regards materials and is now bearing fruit as nearly all new central station installations are designed for at least 900 and some for 950 F total steam temperature.



Method of local stress-relief as applied to a 10-in., 1500-lb, 1000-F, welded bonnet valve

First and foremost among the difficulties presented in valve construction was the trouble in maintaining tight joints, and it was generally agreed that end flanges must be eliminated and welding ends substituted if excellent high-temperature service was to be obtained.

In order to carry out the trend toward higher pressures and temperatures new alloy steels had to be developed which would have excellent creep strength under high-temperature service conditions and at the same time could be welded successfully without air hardening. Seat rings were changed from the so-called flanged ring to the back-seated flexible ring in which all stresses are in compression; and by welding in the seat ring, followed by stress-relieving, an extremely tight and permanent joint was obtained.

Seat rings and disks are now made of extremely hard non-corrosive metals which retain their hardness at high

temperatures and are free from the tendency toward seizing or erosion. Separate faces were abolished and in their place was substituted the solid disk which has many advantages. All disks and rings are ground, lapped and polished to very close tolerance, and the bearing is completely on the disk face instead of ordinary line contact.

Straight waterways are now used in valves, and guides in valves and recesses in disks are carefully machined to close tolerance. Stems with clevis connection are made of stainless steel, heat-treated to high hardness, straightened, ground and polished and the stem threads milled instead of cut. Full-length threaded stud bolts of high-strength, high-hardness alloy steel are used together with oil-quenched nuts, so treated as to prevent sticking. All bolts are set up with special instruments to a predetermined stress, and special packings, gaskets, joints and bypass connections have been designed and constructed. Last but not least, valves are radiographically inspected and tested with kerosene in strict accordance with A.S.A. Standards.

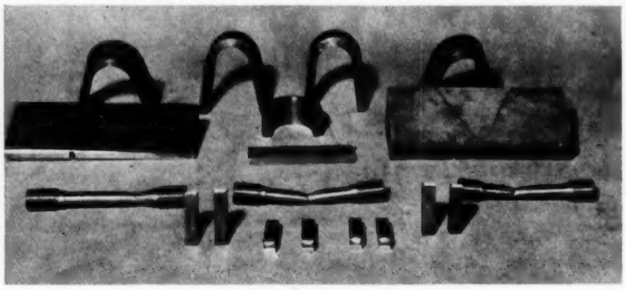
In 1930 the writer carried out a series of tests on the efficiency of bolted joints, especially in bonnet flanges. It was found that the joints would relieve themselves under a fixed or limited strain and with the then prevalent standards of bolting set-up, they showed a tendency to leak after being placed in service if the bolts were not retightened at regular intervals. After much study of the problem it was found that there were available two distinct ways of overcoming this difficulty, both of which have been adopted in our present work.

The first, was to continue the use of the flanged-bonnet joint by obtaining a stud-bolt steel that possessed high physical properties at room temperature so that satisfactory initial gasket compression could be obtained. without overstressing either flanges or bolts. The steel

Preheat coils in place during process of welding

must have good short-time high-temperature properties to compensate for the additional stresses imposed upon it by warming up the lines. High creep strength is also necessary for the valve to maintain its joint when relaxation takes place. It was found that a material with a high initial creep rate relaxes quickly and the residual stress is low; whereas, if residual stress is high so that bolts will stay tight, this indicates that the initial creep effects are small, the material getting a grip on itself with a minimum of internal adjustment.

It was necessary, therefore, to develop a steel for stud bolts that would have high room-temperature properties, high short-time elevated temperature properties, good creep strength at service temperature and remain stable throughout its service life. These properties were



Test pieces from bonnet weld, carbon-molybdenum steel, showing tensile, bend, impact and hardness tests and macro-etch of weld. Depth of weld, 4 in., width at top, 3⅞ in.; number of layers, 40; and number of beads, 86

necessary in order that full advantage could be taken of high stress in the initial bolt set-up to fully compress the gasket and when relaxation did take place in service, the residual stress would be of such intensity as to maintain a tight joint.

As a result of this investigation, Hercules No. 3 stud steel was developed to meet these requirements and is subject to careful manufacture and special heat-treatment. Its great strength at room temperature permits a high initial set-up and when relaxation does take place the creep strength is sufficient to retain a high residual stress and therefore a tight joint. The physical properties of Hercules No. 3 are as follows:

Temperature, deg. F	70	800	1000
Tensile strength, lb per sq in.	160,000	128,000	105,000
Yield point, lb per sq in.	140,000	94,000	80,000
Elongation in 2 in., per cent	16	19	20
Reduction of area, per cent	50	60	63
Impact, Charpy ft-lb	15	..	..
Brinell hardness	330–350	..	..

Laboratory tests of 5000-hr duration have been carried out and extrapolated into terms of one per cent in 100,000 hr, which corresponds to an elongation of one ten-millionths of length per hour. The creep strength of this steel at 1000 F for one per cent in 100,000 hr is 22,000 lb per sq in.

Stress intensities for bolt set-up are obtained from the laboratory in the following manner:

The stud bolt is placed in a tension-test machine with the nuts the same distance apart as they would be in the joint. A block with a hole in it is placed under the bearing surface of each nut and the bolt placed under tension in such a manner that tension pull is applied under the bearing surface of each nut through the bored blocks. The surfaces of these blocks are in contact with the bearing surfaces of the nuts and serve the same function as the outside surfaces of the flanges with which the bearing surfaces of the nuts would normally come in contact. Under these conditions, the stud bolts are subjected to exactly the same conditions as would obtain in the actual joint. The bolt is then subjected to tension, and micrometer caliper readings are taken of the actual overall length of the bolt at equally spaced tension increments.

The bolt is then stressed incrementally up to a point below the elastic limit and then a similiar series of readings are taken as the bolt tension is dropped back to zero. By dividing the tension readings by the area at the root of the thread of bolt, stress intensities extending over the net area of the bolt are obtained. These figures when plotted will give a curve showing the relation between elongation and net stress intensity.

The results are used in setting up bonnet joints in valves and tests are continually made on actual valves set up to determine any permanent set that may have taken place.

As an example of the effectiveness of this method, there is cited the following results of setting up a 12-in., 1500-lb carbon-molybdenum-steel valve with Hercules No. 3 steel. There were eighteen $2^1/_4 \times 15^1/_8$-in. bolts and these were set up to 0.022 in. strain, corresponding to 60,000 lb stress.

Stud No.	Length before set-up, inches	Length after set-up, inches	Length after load release, inches
1	15.1205	15.1425	15.1210
2	15.1265	15.1485	15.1265
3	15.1185	15.1405	15.1190
4	15.1170	15.1390	15.1175
5	15.1250	15.1470	15.1250
6	15.1275	15.1495	15.1280
7	15.1300	15.1520	15.1305
8	15.1370	15.1590	15.1370
9	15.1275	15.1495	15.1275
10	15.1355	15.1575	15.1360
11	15.1280	15.1500	15.1280
12	15.1160	15.1380	15.1165
13	15.1220	15.1440	15.1220
14	15.1215	15.1435	15.1215
15	15.1290	15.1510	15.1290
16	15.1175	15.1395	15.1175
17	15.1420	15.1640	15.1420
18	15.1275	15.1495	15.1275

It may be noticed from this high initial set-up that the bolts, when tension was taken off, returned to their original measurements, thus showing no permanent set.

The second method was to design and construct a welded bonnet valve. Numerous difficulties were encountered here, because in the first place we had to be sure that the interior working parts of the valve would resist the service for the life of the valve. However, with new materials in the seat rings and disk and the welding-in of seat rings, together with non-corrosive packing, it has been possible to go ahead successfully with the design and construction of a welded bonnet valve.

When our investigation was started fusion welding was not looked upon as satisfactory but, due to constant improvements in materials, apparatus and welding techniques, it has become generally accepted as a tool of modern industry. Furthermore, the possibilities of welding have not as yet been fully explored.

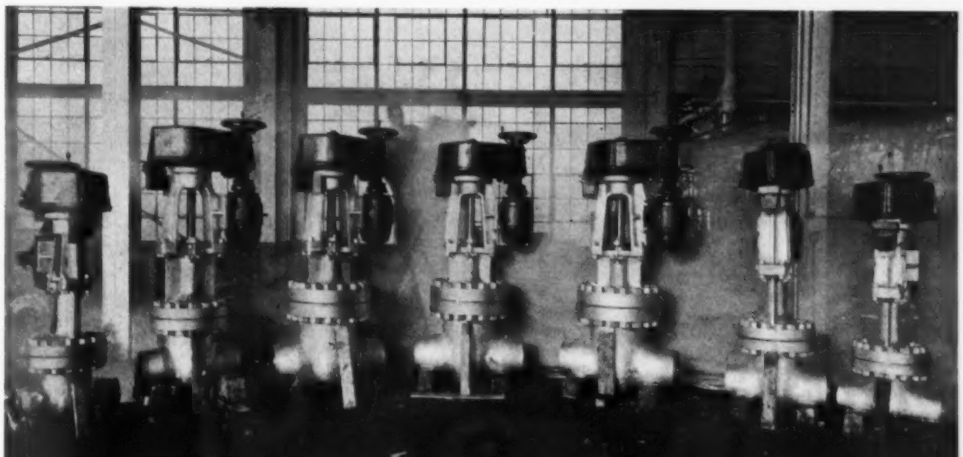
The development of the covered electrode has made it possible to produce sound, clean, strong, ductile welds with practically no limitation in thickness, by the use of multi-layer deposits and the shielding of the arc by the atmosphere obtained from the electrode covering. Further developments have been made in type of welding equipment so that today we use the alternating current transformer type, because it has the advantage of the elimination of the so-called magnetic blow so detrimental to good welding practice. Also, due to the rapid pulsations of the alternating current, the slag formed is thrown to the top where it may be brushed off.

All welding is performed in accordance with proved procedure controls which have been developed through years of experience and practice, and all welding operators are required to pass qualification tests in accordance with standard codes of the insurance companies and the Navy, and then must demonstrate their ability to produce sound, strong, clean, ductile welds. Welds thus made must also pass radiographic and magnetic tests for cleanliness and soundness, and care is exercised to see that welders weld sections of same size and thickness as actual bonnet welds so that strength, impact, bend and metallographic tests can be made.

Unusual methods had to be developed for locally preheating the areas adjacent to the welding groove and maintaining proper temperature throughout the welding operation. The proper joint angle, spacing etc., had to be determined to a nicety and, finally, the entire weld had to be stress-relieved locally at 1200 F, so that any stresses set up by welding would be entirely removed.

Testing of valves before and after welding presented certain problems which have been now overcome.

Last but not least, is the checking of the quality of the weld itself. It was thought for many years that this was impossible without applying some destructive method, but today examination and inspection of welds can be made in any casting by the use of radiography, by which flaws less than one per cent of the thickness of welds up to 1 in. and two per cent in welds up to 4 in. may be readily detected. A standard series of radiographs has been adopted.



Group of 1500-lb, 1000-F, carbon-molybdenum-steel valves with Hercules No. 3 stud bolts and welding ends

A.S.M.E. Annual Meeting

The tentative program for the 1938 Annual Meeting of The American Society of Mechanical Engineers, to be held at the Engineering Societies Building, New York, December 5 to 8, has been announced. The first day, Monday, will be taken up with registration, meetings of Council, sections delegates, professional division delegates and a business meeting at 4 p.m. Of the technical papers to be presented on Monday evening and on the ensuing days the following are of interest to power engineers.

Monday evening, 8 p.m.
SESSION ON THERMODYNAMICS
Reheat Factors for Superheated and Wet Steam Expansion, by Chas. G. Thatcher
The Calculation of Steam-Turbine Reheat Factors, by Ronald B. Smith
Friction Coefficients for the Compressible Flow of Steam, by Joseph H. Keenan
New Measurements of the Specific and Latent Heats of Water and the Mechanical Equivalent of Heat, by N. S. Osborn, H. F. Stimson and D. C. Grinnings

Tuesday morning, 9:30 a.m.
PIPE STRESS PROBLEMS
Determination of the Expansion Forces in Piping by Model Tests, by H. W. Semar
Progress Report on Creep Tests of Tubular Members
Progress Report on Relaxation Tests

Tuesday afternoon, 2 p.m.
POWER AND FUELS
Modern Boiler Furnaces, by E. G. Bailey
Report of Boiler Feedwater Studies Committee, by C. H. Fellows

INDUSTRIAL INSTRUMENTS
Quantitative Analysis of Single-Capacity Processes, by A. F. Spitzglass
Operating Experiences and Graphical Analysis of Automotive Combustion Control, by P. W. Keppler

Wednesday morning, 9:30 a.m.
OIL AND GAS POWER
Five Years Progress of Oil and Gas Power, by H. E. Degler
The Vectorscope—A New Instrument Useful in the Solution of Problems Pertinent to Study and Design of Internal-Combustion Engines, by G. J. Dashefsky

Wednesday afternoon, 2 p.m.
HYDRAULICS
Investigation of Error in Pitot Tubes, by Clyde W. Hubbard
Pitot Tubes in Large Pipes, by E. S. Cole and E. Shaw Cole

LUBRICATION
Thin Oil Films, by Walter Claypoole
Wear in Lubrication Problems, by L. M. Tichvinsky

POWER AND FUELS
The High-Pressure, High-Temperature, Electric Steamship *J. W. Van Dyke*, by L. M. Goldsmith
Industrial Power Plants, by C. W. E. Clarke

Thursday, 9:30 a.m.
FUELS
Possibilities for Utilization of Pulverized-Coal Ash, by A. W. Thorson and John S. Nelles
Progress Report of Fuel-Bed Tests at Hell Gate Generating Station, by M. A. Mayers, W. H. Dargen, Jos. Gershberg, M. J. Williams, E. R. Kaiser and B. C. Dalway

FLUID METERS
Influence of Steam-Flow Metering Equipment on Piping Design, by R. M. Van Duzer, Jr.
Effect of High Temperatures and Pressures on Cast-Steel Venturi Tubes, by W. S. Pardoe
Coefficients of Orifices and Nozzles with Free and Also Submerged Discharge, by R. G. Folsom
Effect of Pulsations on Orifice Meters, by S. R. Beitler
Review of Flow-Nozzle Research with Oil, by E. E. Ambrosius
Pulsating Air Velocity Measurement, by Neil P. Bailey

Thursday afternoon, 2 p.m.
HIGH-TEMPERATURE PROBLEMS
High-Temperature Steam Experience at Detroit, by R. M. Van Duzer, Jr., and Arthur McCutchan
Changes in a High-Pressure Drum to Eliminate Recurrence of Cracks Due to Corrosion Fatigue, by A. E. White

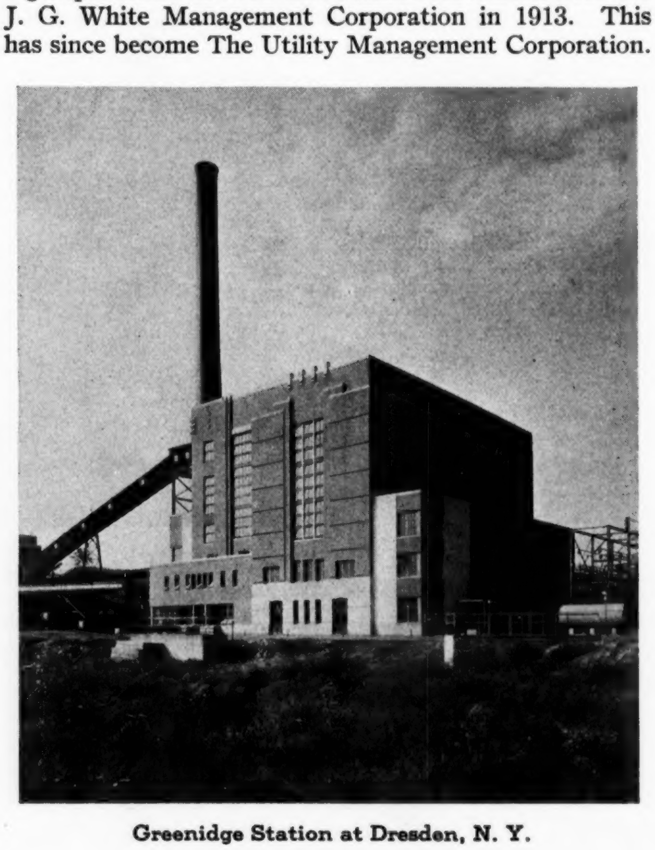
Station Named for C. A. Greenidge

Charles A. Greenidge, vice president and chief engineer of The Utility Management Corporation, New York City, was honored on October 21, 1938 when New York State Electric & Gas Corporation's new steam power plant at Dresden, N. Y., was named The Greenidge Plant. The plant is designed for an ultimate capacity of 90,000 kw in three turbine-generating units, the first of which is installed with a capacity of 20,000 kw. It is served with steam at 700 lb, 825 F by two 110,000-lb per hr three-drum bent-tube boilers fired with pulverized coal.

The dedication ceremony was held in the plant, which is located on Seneca Lake. Ralph D. Jennison, president of The Utility Management Corporation, told of Mr. Greenidge's long career in the field of public utility engineering, and described the high esteem in which he is held by his associates. Harry Reid, president of New York State Electric & Gas Corporation, dedicated the station. H. W. Jefferson, chief engineer of the plant, unveiled the bronze tablet naming the station in honor of Mr. Greenidge. The station itself was described at a meeting of managers preceding the dedication in a talk by J. A. Powell, of The Utility Management Corporation, Reading, Pa.

Mr. Greenidge's Career

After graduation from Stevens Institute of Technology, Mr. Greenidge began his career in the utility industry in January 1896 with the Mount Morris Electric Light Company. From 1902 until 1910 he was with the Utica Gas and Electric Company, where he had full charge of construction. He joined the staff of J. G. White, Inc., New York City, as engineer in the operating department in 1910 and became associated with the J. G. White Management Corporation in 1913. This has since become The Utility Management Corporation.



Greenidge Station at Dresden, N. Y.

Boiler Tests at RIVERSIDE STATION

A digest of the results of tests with pulverized coal and with natural gas on steam generating unit No. 5 at the Riverside Station, Davenport, Ia. This unit has a normal rating of 225,000 lb per hr at 825 lb pressure and 825 F total steam temperature, is of three-drum bent-tube type with a continuous slagging furnace and is equipped with both an economizer and an air heater. On four six-hour tests at outputs from 80,000 to 213,000 lb per hr with coal the efficiency ranged from 88.14 to 87.05 per cent and with natural gas from 85.23 to 84.03 per cent. Additional tests were run to determine the effect of varying excess air on performance. These results and the flow of slag at different ratings are discussed.

IN THE June 1938 issue of COMBUSTION an article by C. A. Butler described the recent extension to the Riverside Station of The United Power Manufacturing Company near Davenport, Ia. This consists of a 28,571-kva condensing turbine-generator supplied with steam at 825 lb, 825 F, from a single steam-generating unit fired with pulverized coal or natural gas and having a continuous slagging furnace. This unit as shown in Fig. 1 is of the C-E three-drum bent-tube type with a rated capacity of 225,000 lb of steam per hour, at which point the guarantees were made, and a maximum capacity of 300,000 lb per hr. The furnace is completely water cooled with both plain and fin tubes on the front wall and fin tubes on the side and rear walls. It is corner-fired and the slagging bottom has a rounded back end for continuous drip into a pit of water. The continuous-loop economizer is located within the boiler setting below the rear drum and bypass dampers are employed for superheat control. A horizontal-shaft Ljungstrom air preheater is provided and the unit is arranged for firing with either natural gas or pulverized coal from three 7 1/2-ton Raymond bowl mills.

Since publication of the description, a series of tests has been run by the power company on the steam generating unit to determine its efficiency at four different loads and to collect operating data for guidance in its future operation. It is believed that a digest of the results will be of interest to many readers, as supplementing the information contained in the earlier description. For these data COMBUSTION is indebted to the engineers of the Moline-Rock Island Manufacturing Company which operates the station.

These tests were conducted with coal at approximately 80,000, 136,000, 185,000 and 213,000 lb of steam per hour and with gas at 80,000, 130,000, 182,000 and 223,000 lb per hr. Tests at maximum rating were not attempted because at outputs above 225,000 lb per hr the forced- and induced-draft fans require the use of their high-speed motors and the control equipment for changing motor speed was not in condition at the time. Also, station load conditions at the time of the test were a factor in fixing the maximum load carried. The unit was operated by the regular firemen during the tests and manual control was employed except for the forced-draft fan which was controlled automatically from the furnace draft. Each of the tests was of six hours duration and the order of running them is indicated by the dates at the top of the table. In addition to the tests at different ratings, runs were made with different percentages of excess air, with the load held constant, in order to determine the influence of excess air on the efficiency and on the steam temperature. These were made with both coal and gas. The curves in Fig. 4 show the effect of excess air on efficiency.

The coal burned was Fiatt and St. David 1 1/4-in.

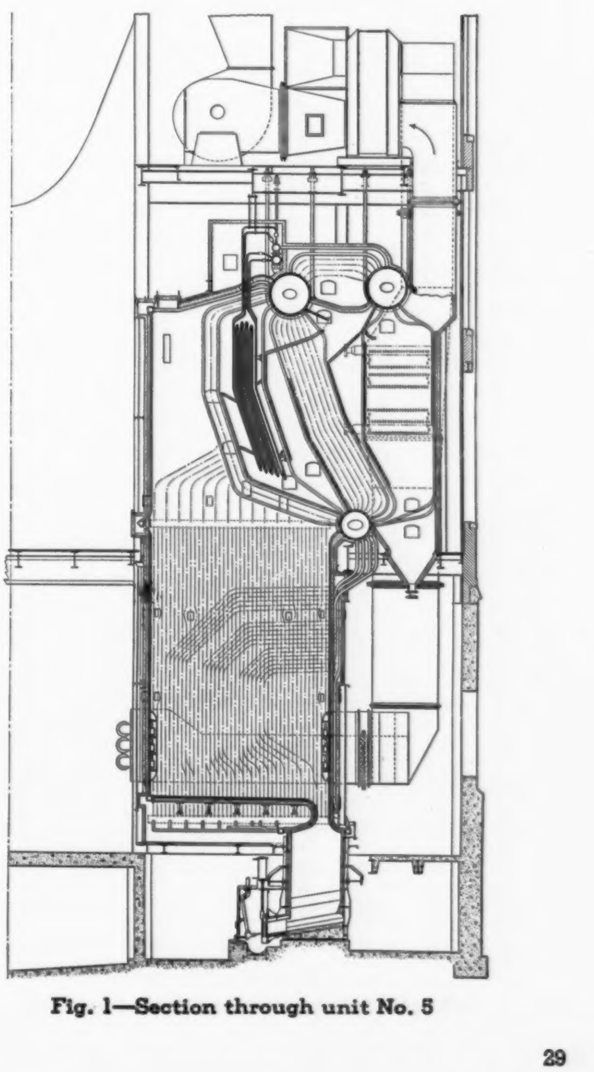


Fig. 1—Section through unit No. 5

screenings from Fulton County, Illinois, as regularly used by the plant. Its proximate analysis was as follows:

PROXIMATE ANALYSIS OF COAL AS FIRED, PER CENT

	Steaming Rates, Pounds per Hour			
	80,000	136,000	185,000	213,000
Volatile	34.2	33.8	32.19	35.52
Fixed carbon	37.86	38.28	38.02	35.52
Ash	12.53	12.82	12.19	10.26
Moisture	15.41	16.10	17.60	16.04
Heating valve	9,969	9,915	10,007	10,149

The ultimate analysis of the coal, which applied to all the tests, was made from a composite of the coal samples taken. It was:

ULTIMATE ANALYSIS OF DRY COAL, PER CENT

Carbon	66.0
Hydrogen	4.60
Oxygen	9.34
Nitrogen	1.70
Sulphur	3.98
Ash	14.38

The natural gas was piped from the Oklahoma fields and had the following analysis, by volume:

ANALYSIS OF GAS, PER CENT

Moisture	0
Methane	80
Ethane	5.5
Propane	3.6
Iso-butane	0.5
Normal butane	0.7
Pentane	0.1
Carbon dioxide	0
Oxygen	0
Nitrogen	9.6
Heating value per cu ft	1045.4 Btu
Heating value per lb	20131 Btu

Comments on Results

A large number of curves were plotted from the results of the tests, only a few of which are here reproduced because of space limitations. The following comments, however, summarize the high spots of much of the information obtained. The efficiencies on both gas and coal (see Fig. 2 and table) were good and fairly flat over the range of loads carried. The values with gas were lower than when burning coal because of the higher loss from burning 0.17 lb of hydrogen per pound of gas, whereas with coal only about 0.06 lb of hydrogen was burned per pound of combustible. However, this is partly offset by the absence of loss from moisture in the natural gas and in the lower dry gas loss. The losses as shown are appreciably less than those predicted, the largest gains being in the dry gas loss due to lower stack temperature, unburned carbon and miscellaneous items, usually referred to as "unaccounted for" losses. The items ordinarily included under this heading are separately listed in the tabulation.

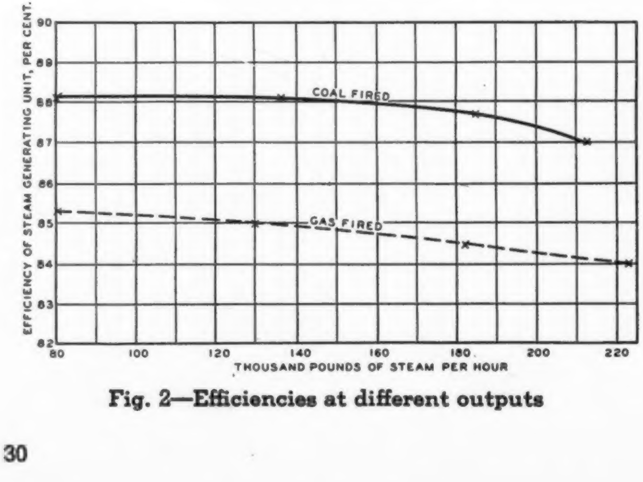


Fig. 2—Efficiencies at different outputs

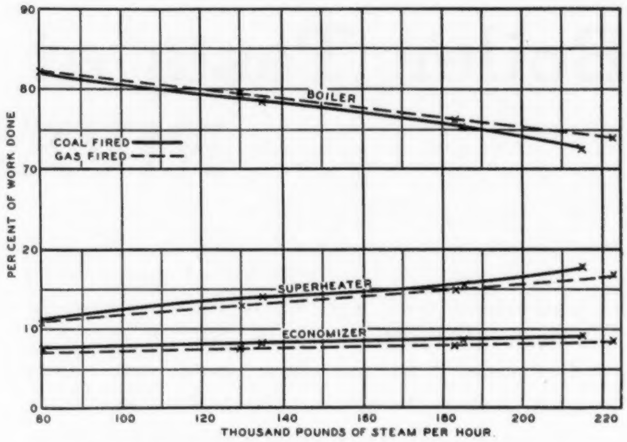


Fig. 3—Division of work at various outputs

The curves in Fig. 3 show the division of work among the several components of the steam generating unit. It will be noted that the boiler and water walls do a smaller proportion of the work as the rate of steam generation increases, while that done by the superheater and economizer increases with increase in output. If the heat absorption by the boiler and the water walls could have been separated it would probably have been found that the boiler does only a small part of the work at low ratings and that its percentage increases, compared with that of the water walls, as the output increases.

The steam temperatures varied directly with the rate of steam generation over the range of loads covered by the tests. The temperature when burning gas is lower because of the lower percentage of excess air, resulting in lower mass flow through the superheater, and because the furnace walls were not coated with slag during these runs. The effect of slagging of the furnace walls on superheat temperature could be noted over the course of the six-hour coal-burning tests. Over this period the steam temperature rose 15 to 20 deg.

The gas temperatures leaving the economizer and the air heater were lower when burning natural gas than with coal which can be attributed to the lower gas volume resulting from lower excess air. On the other hand, the gas temperatures entering the superheater are directly influenced by furnace temperature and were consequently higher with gas, probably because of the higher gas flame temperature resulting from lower excess air. It will be noted that the 185,000 lb per hr coal test temperatures are somewhat low. This test was the first run on coal and was started with the bare furnace walls, before slag had accumulated on them, so that proportionately more heat was absorbed by the water walls on that test.

The draft loss through the unit was somewhat lower than that predicted and was lower when burning natural gas because of the lesser gas volumes.

Steam generator efficiency decreases directly with the increase in dry gas loss, whereas the other losses increase only very slightly with an increase in excess air. On the coal-fired tests at 180,000 lb of steam per hour with varying excess air the efficiency dropped more rapidly with lower CO_2 than when burning gas. This was because the proportion of dry gas to total products of combustion is greater when burning coal than when burning gas. Fig. 4 shows the effect of varying excess air on the efficiency for both coal and gas at 180,000 lb per hr.

Also, the steam temperature rises when the CO_2 is

lowered. This temperature seems to rise more steeply when the excess air is increased while burning coal than with gas, probably because more dry gas is formed when burning a pound of coal than when burning a pound of gas. When burning coal it was necessary to open the superheater bypass damper a few inches in order to hold the steam temperature to the desired value. When the CO_2 was lowered the higher excess air increased the flue gas temperature with both coal and gas. As the CO_2 was lowered on the coal tests the temperature of the gases at the top of the furnace and at the boiler inlet rose, whereas with gas the temperature at these points was lowered. This was likely due to slag accumulations on the furnace walls during the coal run and de-slagging during the gas run.

Effect of Steam Generating Rate on Flow of Slag

At 80,000 lb of steam per hour, or approximately one-quarter maximum rating, the slag began to drip over the nose at the center of the furnace after about two hours of operation. A dam accumulated over the remainder of the nose and large pieces of slag accumulated and dropped off into the water. At 136,000 lb per hr the slag ran freely over about three-fifths of the nose,

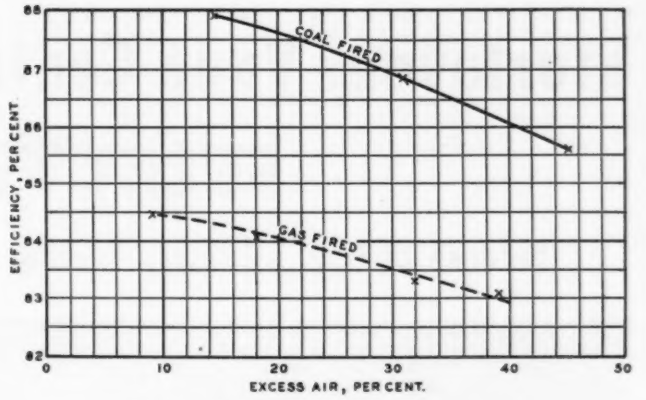


Fig. 4—Effects of varying excess air

the remaining two-fifths being dammed; and at 185,000 lb per hr the slag ran over the entire nose, except for a small area at one side, and was well disintegrated, only a few large chunks being found on the disposal screen after the fine ash had run through. At 213,000 lb per hr the slag ran freely over the entire nose and its disintegration was excellent.

In the variable excess air tests it was found that the slag ran more freely as the CO_2 was increased.

RESULTS OF TESTS ON NO. 5 STEAM GENERATING UNIT, RIVERSIDE STATION, DAVENPORT, IA.

	Burning Coal				Burning Gas			
Date of test	8-6-38	8-4-38	8-3-38	8-9-38	7-30-38	7-29-38	7-28-38	8-2-38
Duration of test, hr.	6	6	6	6	6	6	6	6
Steaming rate, lb per hr	80,000	136,000	185,000	213,000	80,000	130,000	182,000	223,000
Pressures								
Superheater outlet, psi, gage	822.8	824.1	821.3	822.2	825.7	824.4	828.1	826.7
Economizer inlet, psi, gage	978	985	992	1,015	987	1,003	993	1,001
Air heater inlet, in. water	1.03	2.46	4.04	5.48	1.40	1.97	2.87	4.20
Air heater outlet, in. water	0.63	1.57	2.45	3.42	1.03	1.37	2.27	2.48
Fuel at burners, psi	....	....	....	....	1.8	4.4	8.4	12.3
Draft, in. of water								
In furnace	0.21	0.23	0.26	0.31	0.22	0.22	0.24	0.26
Entering boiler	0.16	0.16	0.20	0.20	....	....	....	....
Boiler outlet	0.46	1.13	2.29	2.94	0.40	0.97	1.80	2.60
Economizer outlet	0.40	1.52	3.22	4.08	0.41	1.21	2.50	3.78
Air heater outlet	0.76	2.18	4.76	6.27	0.62	1.61	3.60	5.58
Temperatures, F								
Boiler room	90	92	97	96	90	89	86	93
Superheated steam	667	732	772	832	666	714	764	799
Water to economizer	210	210	212	213	210	210	210	210
Water entering boiler	297	308	320	331	294	302	314	319
Gases entering boiler, avg.	1,251	1,472	1,583	1,757	1,298	1,518	1,665	1,796
Gases entering superheater, avg.	1,105	1,302	1,376	1,539	1,139	1,282	1,463	1,596
Gases leaving boiler	597	685	740	815	570	638	709	761
Gases leaving economizer, avg.	358	422	456	505	336	375	420	459
Gases leaving air heater, avg.	240	271	291	320	231	253	277	294
Flue gas analysis, per cent								
Boiler outlet, CO_2, avg.	15.05	14.88	14.74	15.22	10.61	10.42	10.45	10.66
O_2, avg.	3.77	3.87	3.84	3.72	2.22	2.41	2.21	1.99
CO	....	....	....	....	....	.....	.....	.....
Air heater outlet, CO_2, avg.	12.95	13.62	13.69	13.96	9.88	9.74	9.75	9.98
O_2, avg.	6.04	5.36	5.26	4.97	3.37	3.63	3.61	3.21
CO	....	....	....	....	....	.....	....	....
Evaporation, lb								
Per lb of coal as fired	7.737	7.415	7.306	7.141	....	....	....	....
Per 10 cu ft of gas	....	....	....	....	7.881	7.561	7.337	7.246
Per 10,000 Btu	7.761	7.479	7.301	7.036	7.510	7.277	7.047	6.887
Refuse analysis								
Per cent of fuel as fired	12.53	12.82	12.19	10.26	....	....	....	....
Per cent of combustible (fly ash)	7.19	5.13	5	4.75	....	....	....	....
Btu per lb combustible in fly ash	5,895	5,895	5,895	5,895	....	....	....	....
Losses, per cent								
Dry flue gas	3.81	4.25	4.59	5.18	2.66	3.15	3.63	3.80
Combustion of H_2	4.04	4.08	4.00	4.06	10.31	10.50	10.58	10.53
H_2O in coal	1.71	1.82	1.98	1.80	....	....	....	....
H_2O in air	0.11	0.10	0.15	0.19	0.08	0.09	0.09	0.13
Unburned carbon	0.27	0.20	0.18	0.14	....	....	....	....
Unburned gas	....	....	....	....	0.10	0.10	0.10	0.10
Radiation	1.46	0.85	0.62	0.54	1.46	0.90	0.63	0.51
Heating of water in slag pit	0.16	0.31	0.54	0.74	0.16	0.29	0.55	0.90
Heat in slag	0.22	0.22	0.22	0.22	....	....	....	....
Mill tailings	0.08	0.08	0.08	0.08	....	....	....	....
Total losses	11.86	11.91	12.36	12.95	14.77	15.03	15.58	15.97
Efficiency, per cent								
By heat balance	88.14	88.09	87.64	87.05	85.23	84.97	84.42	84.03

Purchase of Coal from Consumers' Viewpoint

By A. W. THORSON

The Detroit Edison Company

At the Joint Fuels Meeting of the A. S. M. E. and the A. I. M. E. held in Chicago, October 13 to 15, one session was devoted to a Panel Discussion at which papers were presented representing the viewpoints of the coal producer, the coal salesman, the purchasing agent and the consumer. Mr. Thorson's paper deals with the consumers' problem from the angles of reliability of supply and the value of the particular coal, in which are discussed such factors as ash-softening temperature, sulphur, size, weathering and caking properties, grindability and rate of burning.

FROM the viewpoint of the coal consumer, two important questions must be answered in connection with each coal purchase: first, How reliable is the source of supply? and second, What is the value of the coal?

The answer to the first involves many factors, among which are, stability and integrity of the producing company, transportation facilities, continuity of supply, production capacity, character and uniformity of coal seam, mining conditions and preparation and control of the shipped product. It is not the purpose of this paper to attempt a general discussion of these factors, but rather to emphasize that they shall be considered. The effect of each must be weighed in each case and a balance reached by those responsible for the purchase of coal.

The second question, "What is the value of the coal?" must be answered by those responsible for operation of the plants burning the coal. Where large tonnage is involved, small differences in coal value become large annual sums. It is necessary, therefore, that competitive fuels be evaluated with the utmost care and precaution, in order that the result will be an accurate guide to purchasing.

Such evaluation is not simple. Many factors and quantities are involved, and some of these cannot be appraised until considerable experience has been accumulated with the particular coals. Too often coals are evaluated merely on the basis of heating value, moisture and ash content. Although these properties are of primary importance, one may be grossly misled by the assumption that such a comparison is final or nearly so. It merely compares the price of heat units delivered to the plant. A complete comparison must include the effect of the coal properties upon every phase of operation and maintenance expense from the coal pile to the stack, and out to the refuse pile. Such a comparison must be made for each plant and perhaps for several types of equipment in the same plant. The final result frequently reveals that the most economical coal, when considering the price of delivered heat units only, is the least economical in the final analysis because of increased plant expenses resulting from its characteristics.

The usefulness of moisture, ash and heating value for coal evaluation is generally recognized. Attention is therefore invited to a consideration of some other coal properties and how they affect coal value.

Ash-Softening Temperature

The fusion characteristics of coal ash are extremely important in steam plant operation. Clinkering and slagging are major operating problems, and a means of predicting clinkering accurately from the chemical properties of the ash is yet to be found. Ash-softening temperature is the best index available, but it is only one factor in a complex action and is therefore misleading at times. In spite of this, experience has developed certain relationships between ash-softening temperature and other properties which are valuable in deciding the minimum tolerable fusion value for a given plant and load. In the absence of better information, purchasing must be guided by this experience.

In many cases, the minimum fusion value is set by furnace size. Ideally, the furnace should be proportioned so that the temperature of the flue gas leaving the furnace and striking the first bank of boiler tubes shall be below the ash-softening temperature, thereby minimizing tube slagging. This applies to both stoker-fired and pulverized-coal-fired furnaces. In practice, however, a compromise must be reached. To satisfy this condition at maximum ratings an extremely large furnace would be necessary, whereas reduced ratings would call for an extremely large superheater, because the large furnace reduces the gas temperature at the superheater. If, however, the unit is to operate normally at high ratings, the need for a larger superheater vanishes, and the investment in a large furnace may be justified. Whatever compromise is reached will be reflected in operation. Use of lower-fusion coals or higher burning rates than normal will be accompanied by increased slagging.

It is apparent, therefore, that once a furnace is designed, the minimum ash-fusion value is set and nothing but reduced load requirements will permit the use of lower-fusion coal. On the other hand, fusion values higher than necessary do not add to the value of the coal. In the case of slag-bottom furnaces, higher fusion may even be a disadvantage and, conversely, low fusion may command a premium price, where furnace design and load requirements make it difficult to keep the slag in the molten state.

Consideration of these facts leads to the conclusion that coal value in general does not vary with ash-softening temperature, and any attempts so to adjust coal prices are without foundation. The allowable range of fusion values must be determined by experience in each plant, and purchasing must then be guided by it.

Sulphur

The importance of sulphur content in coal has been possibly over-emphasized. It is true that high sulphur usually accompanies other undesirable properties but, in itself, sulphur content is not a good index of clinkering,[1] nor of spontaneous heating.[2] Moreover, one cannot predict the amount of tube and furnace slagging from the sulphur content. Coal washing in many cases reduces the total sulphur content, increases the ash fusion and decreases tube slagging. The volatile sulphur compounds seriously raise the dew-point of flue gases, thereby increasing the danger of sulphuric acid formation and the corrosion of heat transfer equipment. The rate of such corrosion must be determined for various coals and allowance made for maintenance. Failure to recognize this item may prove costly.

Weathering Properties

The ability of a coal to withstand exposure and spontaneous heating must be considered where coal is to be stored. Coal which tends to heat in storage or which slacks badly and carries excess moisture when reclaimed will increase operating costs. These effects must be considered in evaluating the coal.

Caking Properties

For stoker firing, the caking properties of a coal are very important. It is unfortunate that measurement of this property has not been standardized, and very little data are available. As a result, the effect of varying caking properties upon operation must be relegated to evaluation by burning test.

If the coal is weak in caking power, the carbon loss to the ashpit may be excessive. If too strong, it may increase the fuel-bed resistance to a point where the boiler capacity is reduced. Change from a coal with unsuitable to one with suitable caking properties may reduce operating and maintenance expenses appreciably.

Coal Size

Sizing receives little attention in the power plant. On stokers, different sizes of the same coal will exhibit different caking properties, and will burn at different maximum rates. These variations should be investigated, because a plant with just sufficient capacity might change to a different size coal and avoid investment in new capacity. Carbon in the refuse, stack losses and smoke emission are all functions of size, and the subject must receive more study if sizing is to be properly evaluated.

It is generally assumed that the size of a pulverizer fuel is unimportant. In some of the older bin systems, however, facilities for drying the coal are limited. The smaller sizes may pick up moisture in transit or in storage to such a degree that driers and mills will be plugged with wet coal. Where such conditions prevail, size may become extremely important to continuity of plant operation, and a higher-priced, larger-sized coal justified.

[1] "The Sulphur Problem in Burning Coal," by J. F. Barkley, U. S. Bureau of Mines Technical Paper No. 436, 1928, p. 3.
[2] "Spontaneous Heating of Coal," by J. D. Davis and D. A. Reynolds, U. S. Bureau of Mines Technical Paper No. 409, 1928, p. 41.

Grindability rating of coal is not important to the pulverizer plant that has ample mill capacity. In such a plant, a high grindability does reduce the grinding cost, but auxiliary power is cheap within the plant, and a reduction of even half the total power cost of pulverizing would warrant only an insignificant addition to the price of coal.

Rate of Burning

Although not solely a property of coal, the rate at which each coal can be burned in a given plant must be known. This may be limited by the ignition rate of the coal, its ash-fusion temperature, emission of smoke or fly ash and many other factors. A coal may be apparently the most economical of all those available, yet because of some limitation, the allowable maximum rate of burning may be below that necessary to carry the load. Unless the saving resulting from the use of this coal warrants a design change or investment in added capacity, this apparent economic first choice cannot be adapted to the plant. Nor is it suitable if the necessary burning rate is carried at the expense of increased maintenance, where the installed boiler capacity is just sufficient. The resulting increased outage in such case will reduce capacity of the plant.

In the Detroit Edison Company, coal is purchased according to the following method:

A continous search of the market indicates possible sources of supply. Trial shipments are sampled and analyzed, and evaluated on delivered heat-unit basis. If promising, larger shipments are tested in the plant, and operating expenses and maximum allowable burning rate are determined. Storage properties are tested. If suitable, the coal is purchased regularly and the equipment carefully watched for evidence of increased maintenance. Under this procedure, the puchasing and operating departments cooperate in an effort to produce the lowest overall fuel cost.

Summary

The aim of those connected with the utilization of coal for steam generation is to improve overall cost economy. There are two general methods: increasing boiler-room efficiency and selecting more economical coals. The farther the plant is from its source of supply, the more important the differences in efficiency become; the nearer to its source, the more important differences in coal value become—the term, "coal value," referring to the summation of delivered coal cost, handling and burning costs and all resulting changes in operating and maintenance expenses.

The efficiency limit is principally in the hands of the designer. Once the plant is built and properly operated, improvement in economy is limited to purchase of more economical fuels. Determination of coal value can be accomplished only by proper coordination of market conditions, plant equipment and load requirements. Many limitations are placed on coal buying by design; others by age or condition of equipment; still others, such as sulphur content, size, caking properties and ash fusion are governed by experience and load requirements.

It is important that these limitations be not only recognized but that they be proven to be real, for in the words of Gould[3], "failure to see the real absence of coal-buying limitations is just as costly as their existence."

[3] "Buying Coal for Profit," G. B. Gould, *Power*, April 28, 1931, p. 663.

New Topping Unit for L Street Station, Boston

By GEORGE A. ORROK, JR.
Boston Edison Company

In this paper, presented at the Fall Meeting of the A. S. M. E., Providence, R. I., on October 5, the author reviewed the engineering studies leading to selection of steam conditions, sizes and types of equipment best meeting the requirements for topping the existing 300-lb turbines at the L Street Station of the Boston Edison Company. The extension includes two 375,000-lb per hr pulverized-coal-fired boilers supplying steam at 1200 lb, 910 F, to a 20,000-kw high-pressure turbine-generator exhausting at 300 lb.

THE existing equipment in the L Street Station has a capacity of 198,000 kw, which is augmented by tie lines from the Edgar Station ample to carry the peak loads which were anticipated for the near future. However, 96,000 kw of this capacity consists of eight vertical turbines served by forty-eight 200-lb pressure boilers, which naturally are quite uneconomical to operate. The remaining 102,000 kw of capacity consists of three horizontal turbines served by twelve 300-lb pressure boilers. These turbines are in good condition and can give many more years of useful service. The boilers, however, are not comparable to modern units in economy.

With these conditions, it was apparent that a superposed high-pressure unit at this station would make desirable fuel savings: first, it would provide economical boiler capacity for the horizontal turbines; second, the addition of the high-pressure turbine would form a generating unit with economy comparable to the best; third, the 300-lb boilers released would give a reliable source of steam to operate the vertical turbines for peak load service.

Preliminary economic studies confirmed the general conclusions just stated. Various schemes were estimated. Load duration curves were prepared from which the power generated by the new units was calculated and the operating savings determined. These savings were capitalized and plotted with the costs. This analysis indicated that a topping unit of rather small size, over the 300-lb turbines, would earn the best return on the investment. Other types and sizes of units could not be justified by savings, and, even if greater capacity were later needed, the study indicated that the topping unit should be installed first. The decision was made to purchase a 20,000-kw high-pressure turbine, which was the standard size nearest in capacity to the economic size.

The next question was to select the heat balance. At present, condensate at 185 F is discharged from the 300-lb turbines after passing through oil and air coolers and barometric heaters. The barometric heaters condense the steam from the exhaust of the existing steam-driven auxiliaries.

Since the top will deliver less steam than is required by the 300-lb machines, there will be a surplus of condensate at normal station loads available for the high-pressure boilers. For periods of light loads, adequate condensate storage will be installed. This means that the 300-lb boilers will serve as evaporators for makeup to the high-pressure boilers.

This decision to use 185-F condensate at once made definite the proper heat balance. It was apparent that the new oil and air coolers must be cooled from some other source of water. Fortunately, a convenient supply was found in the salt water pumped to the gas scrubbers installed in the two chimneys serving the 300-lb boilers. The salt water will pass through a heat exchanger and cool a circulating fresh-water system supplying the generator air and oil coolers and the bearings of the station auxiliaries.

Cross-over Heater Not Justified

Early studies had considered a deaerating and a cross-over heater. More complete analysis, however, showed that a cross-over heater could not be justified, for the following reasons: Considerable difference exists between the efficiency of the 1200-lb and the existing 300-lb boilers. The top supplies steam for only a part of the 300-lb turbines; hence some of the 300-lb boilers must be run the greater part of the time to operate the remaining turbines. Any steam taken at 300 lb for heating the feedwater of the 1200-lb boilers would mean increased operation of the low-efficiency 300-lb boilers. This would cause a thermal loss greater than any possible gain in cycle efficiency. It is believed that this will be found generally true where topping units are installed which do not cover the entire low-pressure plant.

This same argument might have been extended somewhat to bleed heating at lower pressures. However, since heating to deaerating temperatures was necessary, and as the reliability of turbine-driven boiler feed pumps seemed desirable, a balance was found between boiler feed-pump power requirements and steam for deaeration, at a pressure of 55 lb gage, corresponding to a feedwater temperature of 300 F.

With these decisions made, the addition of a gland steam condenser in the line to the deaerator completed the flow diagram and the heat balance, as shown in Figs. 1 and 2, respectively.

As the study of the heat balance had considered only the normal source of power for driving the boiler feed pumps, the general question of auxiliary power next required attention. Twenty-three-hundred-volt alternating-current motors were finally chosen, based on the present practice in the more modern stations and the difficulty and expense of procuring direct-current motors of adequate size and speed (1250 hp for the boiler feed pumps and 1000 hp for the induced-draft fans).

Metal-enclosed switching equipment has been provided for controlling the 2300-volt auxiliaries of the new unit and feeding the transformers for the lower voltage power and lighting services. The circuit-breakers are of the Deion air-break type. This equipment is mounted in a separate room from the main switchboard and functions as a substation by itself.

Having roughed out the basic design, the next step was the selection of equipment. The turbine-generator specifications offered little of particular interest, with the exception of the large-sized kva generator and the possibility of future operation at 200 lb back pressure. The steam conditions of 1200 lb and 900 F were determined since expansion from this condition gave exhaust steam of the proper temperature for the existing 300-lb 625 F turbines, and also for the 200-lb 525 F turbines.

As finally purchased, the turbine-generator has a nominal rating of 20,000 kw; the generator, 37,500 kva, to correct a deficiency in kva capacity in existing units, caused in part by rating up existing turbines. Actually, the turbine is expected to have a capacity of 25,000 kw at 300 lb and 31,250 kw at 200 lb back pressure. The speed is 3600 rpm, which with the throttle conditions of 1200 lb and 900 F, gives the lowest cost machine. In the comparison of bids, no very good case could be made for hydrogen cooling of the generator for this size of machine. The cost was higher and operating difficulties were feared.

Normal excitation is supplied by a direct-driven exciter and pilot exciter, the manufacturer convincing the purchaser that commutation at 3600 rpm would be satisfactory.

The generator is equipped with a CO_2 system of fire protection.

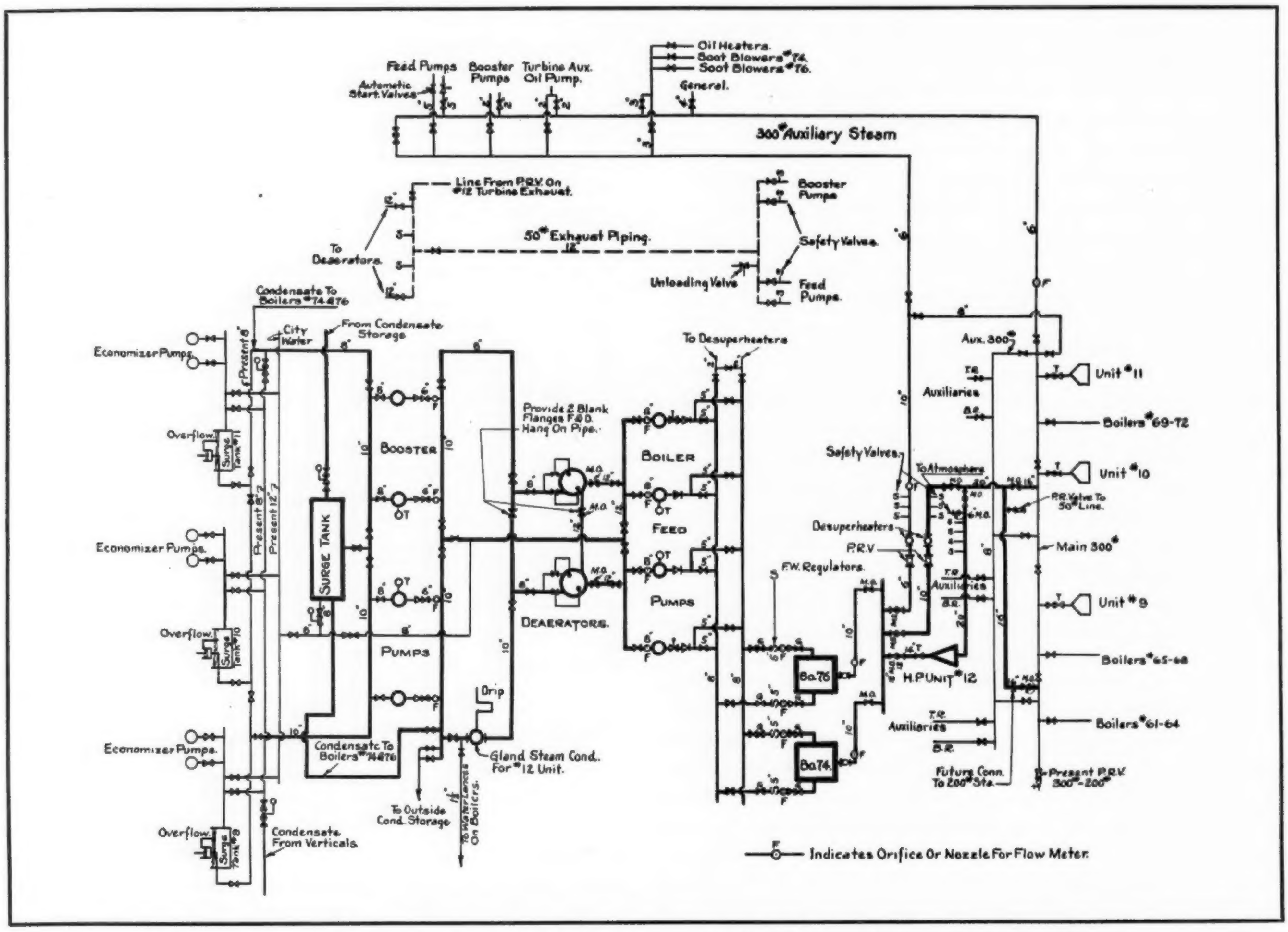


Fig. 1—Diagram of connections for high-pressure boilers and various auxiliary equipment

Steam Generating Units

The boiler specification offered a few more problems. The decision in favor of pulverized coal rather than stoker firing was made with little discussion despite the fact that all the previous electrical generating experience of the company had been with stokers. However, at the Kneeland Street steam heating plant there is a modern pulverized-coal installation of comparable capacity, and studies showed that first cost, reliability, maintenance and operating cost all favored pulverized-coal firing for L Street conditions.

With pulverized coal it was possible to design the ignition oil torch system to use heavy oil and provide relay capacity for the loss of a pulverizer at little expense. The system can be extended for full capacity oil burning if desired in the future.

At Kneeland Street slagging has never been a problem, perhaps because of steam heating load factors. However, boiler cleanliness has always been a serious problem in the stoker-fired plants; hence a very important part of the specification was devoted to securing a boiler which could be maintained clean. To this end the furnace heat release was specified at 25,000 Btu per cu ft maximum and various clauses were added to give as low a gas temperature entering the boiler tubes as was consistent with the desired superheat. The boiler purchased (see Fig. 3) has these features and gas will enter the first tube row at 2100 F which is below the softening temperature expected in the ash.

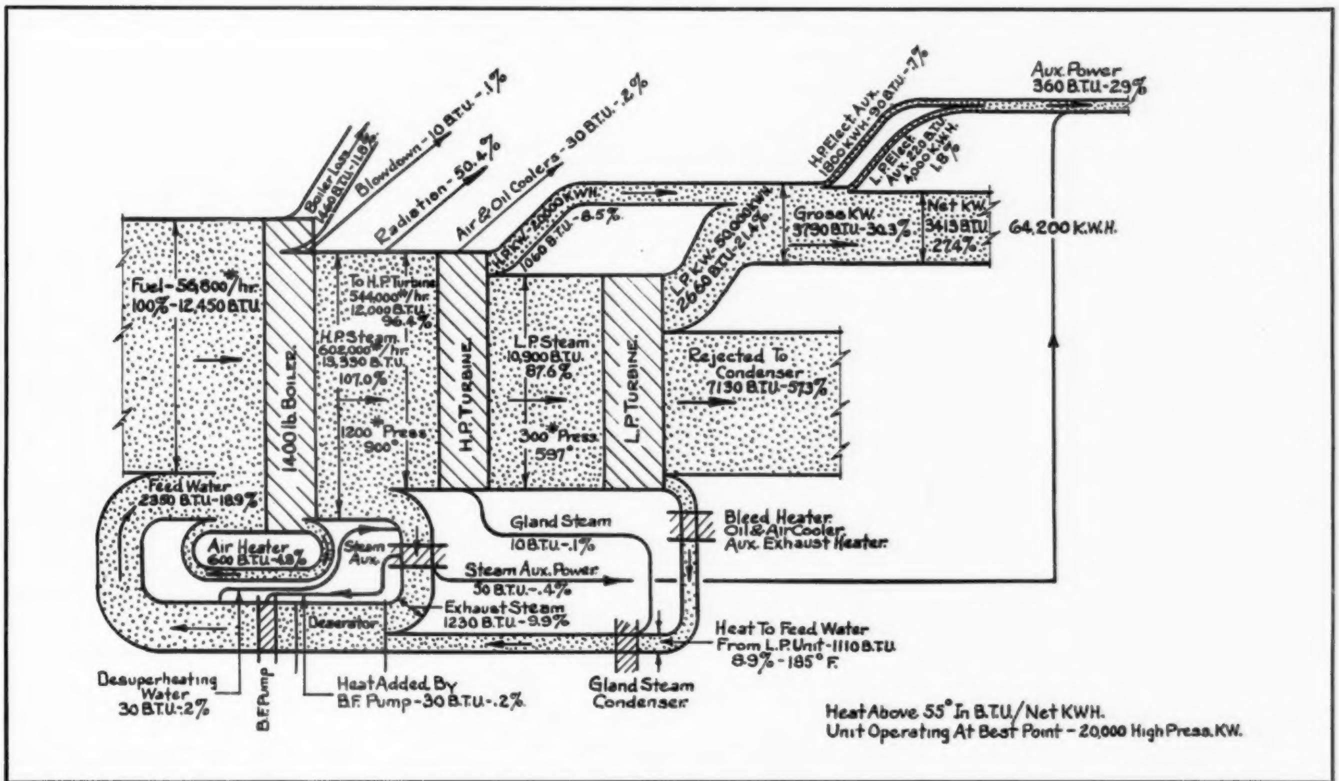


Fig. 2—Heat flow diagram for L Street Station

Another problem occurred in superheat control required by the close limits necessary with 910 F steam. Despite the excellent performance of radiant superheaters elsewhere, it did not seem wise to become involved in their design problems, and this left damper control as the desirable alternate. A mistrust of dampers in general and hot dampers in particular led to the specification that maximum gas temperature at the damper be less than 1325 F. The final design is a multiple-hinged leaf damper with individual rod operators for each leaf.

The boiler manufacturer did not offer his special tangentially fired furnace because it was not considered advantageous for a small-sized dry bottom unit. However, by firing horizontally under the mud drum, there will be a very effective use of the furnace volume and little tendency to plaster slag on the lower part of the boiler tubes.

The next item studied was dust catchers. Here the only important specification was high efficiency, and bids were received on electrostatic, wet scrubbers, and mechanical-type dust catchers. In the comparison, there were figures on the maintenance cost of wet scrubbers at the Kneeland Street heating plant and on various mechanical types at the generating stations. Data were collected from other companies on the performance and operating cost of the Cottrell type. A careful comparison of the cost to own and operate equipment of adequate efficiency (better than 90 per cent) was made, as a result of which electrostatic precipitators were purchased.

This decision determined the final draft conditions which showed that the fans for L Street would require 1000-hp motors. The most reliable type available was the constant-speed induction motor. Fan bids were received on vane control, hydraulic coupling control, and on dual-vane control, with forced- and induced-draft fans on one shaft. Again maintenance and operating costs received careful attention. The efficiency of variable capacity devices at partial loads was considered and the results applied to a load duration curve. Although the dual fan showed somewhat the better on cost comparison, the decision was finally made to purchase vane controlled forced-draft fans and hydraulic-coupling-controlled induced-draft fans. The advantage of separate units and reduced wear of the variable speed induced-draft fan overbalanced any slight cost consideration.

This investigation showed large-sized hydraulic couplings in a very interesting stage of development. In the earlier couplings, one-half of the coupling had been

mounted on the motor shaft, the other in a pedestal bearing, with a thrust bearing between the two halves. A second development had removed the internal thrust and substituted a special thrust bearing built into the motor bearing. The third and final design, existing on paper only at the time the order was placed, consisted of two pedestal bearings, each with a thrust bearing. One shaft extends through the hollow shaft of the other, with internal bushings. The whole forms a complete unit connected to the motor and fan with flexible couplings. This design and the development work were carefully reviewed and finally adopted, although in the design of this unit there was no intention to pioneer.

The selection of boiler-feed pumps was relatively simple since a number of designs were available, with very good performance records. The Company's experience with 1400-lb pumps had provided judgment as to the details. The pumps selected were of relatively small capacity, 400,000 lb per hr each, 3600 rpm, and complete 100 per cent spare capacity. Two were motor-driven and two turbine-driven.

Piping Design

During this time the question of piping design had been studied. The practice of the Company had taken up welding gradually. For many years the steam mains of the district heating system had been welded because their inaccessibility required the most permanent form of joint. In 1927 the economy of welding low-pressure condensate and bleeder steam lines was recognized and employed at Edgar. In 1930 at Kneeland Street, one step farther was taken, and boiler-feed lines were welded. For this L Street installation, it was apparent that flanged joints for 1400 lb and 910 F were not well standardized, although the experience with Sargol joints at 1400 lb and 750 F had been satisfactory. A rough study of joint costs, based on unit prices submitted by piping companies, led to the following general conclusions:

> At low pressures flanged pipe is cheaper than welded pipe for the larger sizes.
> At high pressures welding is cheaper than flanging.
> Screwed joints cost one-half as much as other types.

Welded construction among neighboring companies appeared to be giving satisfaction. Therefore, it was decided to employ welding as much as possible throughout the installation. Welding was indicated for the valves of high-pressure steam lines since the only alternative was seal-welded Sargol joints at a greater expense. Low-pressure valves and most high- and low-pressure water valves were flanged, since adequate joints were available for these services.

On the basis that remote operation is necessary and that the cost of full automatic control adds little to the cost of remote controls and instruments, full automatic combustion control has been used by the Company. In selecting the equipment, considerable weight was given to the measurement of fuel-air ratios by fundamental measurements such as CO_2 or steam flow-air flow, rather than by feeder speeds, etc. The control selected is air-operated—the master, "more or less," impulses coming from steam pressure. Fuel feed is regulated directly from the master; steam flow-air flow controls the induced-draft fan, while furnace draft is regulated by the faster vane-controlled forced-draft fan. In making this last decision, the old familiar discussion as to whether forced draft or induced draft should control furnace draft was encountered. With fans and controls of equal speed of response, it should be obvious that there is no choice in this matter, since both act in a simple series circuit. In this case, with the hydraulic-coupling-driven induced-draft fan considerably slower than the vane-controlled forced-draft fan, the argument was reduced to whether it was more important to have

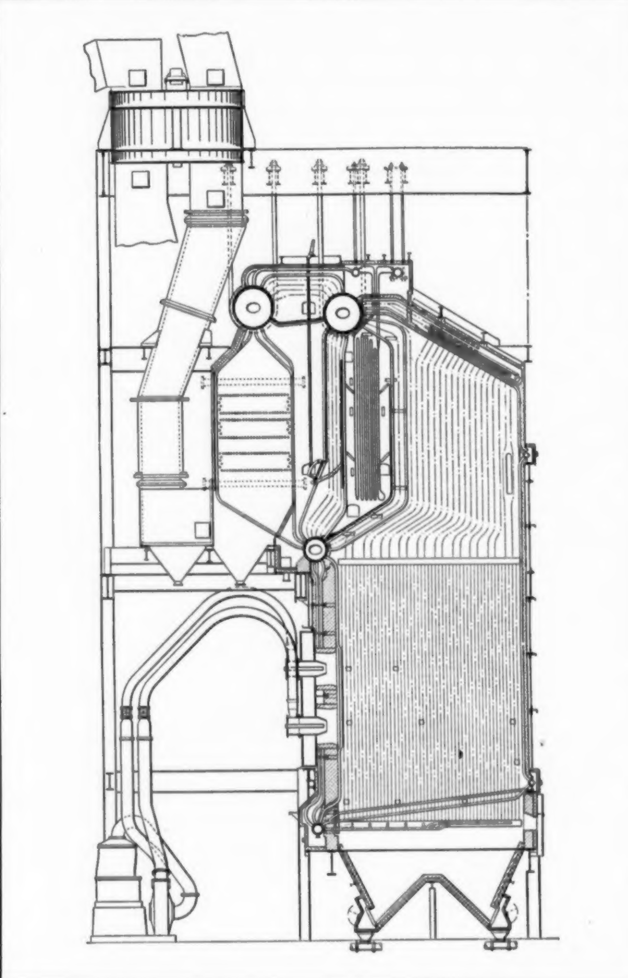


Fig. 3—Section through one of the two high-pressure steam generating units

the furnace draft or the total air flow correct under transient conditions. The decision was made in favor of the furnace draft, which regulates ignition and possible puffs of flame through access doors.

Superheat is regulated by a damper, as previously mentioned, and this is automatically controlled from temperature regulators in the leads from each boiler. These instruments are mastered by a third temperature regulator in the turbine exhaust, which protects the existing low-pressure equipment from excessive temperatures.

Temperature control and protection are further provided by the pressure reducing and desuperheating equipment. The principal item is the large bypass line around the high-pressure turbine of 800,000-lb per hr capacity. This will function to supply low-pressure steam in case of trip-out or when the turbine is out of

service. It is fully automatic, the reducing valve being controlled by downstream pressure and the desuperheater by steam flow and downstream temperature. A smaller bypass is provided for low loads and to supply steam to the auxiliaries in case excess high-pressure steam is available. Auxiliary desuperheating nozzles are provided in the turbine exhaust as a final guarantee that temperatures to existing equipment will not be dangerous.

The final piece of automatic-control equipment was made necessary by the close clearances of the 3600-rpm high-pressure boiler-feed pumps. These pumps at full shut-off will overheat and seize in a very few seconds. Since, in the parallel operation of steam and motor-driven pumps, shut-off of a pump might frequently occur, boiler-feed-pump bypass control is required. Its primary function is to open a bypass around the pump and thus keep the pump cool. This control must act rapidly, and it was considered best to have it actuated by the fundamental measurement of water flow to the pump.

It was also desirable to control the discharge pressure of the pumps so that motor- and turbine-driven pumps would parallel and keep a stable constant excess pressure for boiler-feed regulation. For this purpose, an air-operated control actuated by excess pressure varies the turbine governors and positions throttling valves in the motor-driven pump discharges.

Having provided these two devices, the additional cost of complete flow-ratio control seemed small, and it was accordingly purchased so that the various pumps in parallel can be set to carry any desired fraction of the load.

Ash-Handling System

Another piece of apparatus that gave considerable food for thought was the ash-handling system. Experience in the various plants, which has covered all types of apparatus, including pneumatic conveying, in a small way, proved that all of these methods require considerable handwork and could stand further development.

This case differed from the others because of the large quantities of dry dust expected from the Cottrell precipitators. Investigations disclosed that this dust could be well handled pneumatically once it could be started into the feeders. Further investigations disclosed that pneumatic handling even of the ashpit refuse was practical and offered advantages of accessibility for hand manipulation of hard, large clinker formation. Therefore complete pneumatic ash handling equipment was purchased, special care being given to make the hoppers steep sided, and vibrators were provided where trouble was anticipated.

The ash conveyor piping discharges through a centrifugal separator and bag filter to a cylindrical tile tank, which empties into ash trucks through a rotary mixer, in which water is added for dust control.

Throughout the design of the plant, an effort has been made to balance investments against operating costs. This is somewhat in contrast to the old principle that the best is none too good. The difference can be plainly seen in the power plant building itself, where glazed tile of intricate pattern has given place to simple partitions of hollow tile. Stair rails are simple pipe railings instead of ornamental castings with brass rails. The money has been spent only where the earning power of the investment could be demonstrated.

One other contrast in the building should be mentioned, and that is the structural steel frame. In the new extension, the progress of power plant design gave heavier loadings, more auxiliary equipment, dust catchers, deaerators, and the chimney supported on the building. In consequence, it was economical to design our steel as a continuous frame, by the Hardy Cross moment distribution method. This design, which permits the utilization of fixed connections of beams to columns, achieves economy by reducing the size of beams and girders, taking some of the moment in the columns. Since wind bracing was also eliminated by increasing the stiffness of connections, there are some very unusually heavy connections in the steel.

This superposed extension is not yet in operation. The Boston Edison Company has confidence that an economical investment has been made because of its experience at Edgar Station and because of studies similar to those discussed in this paper. Jackson & Moreland, of Boston, were consulting engineers on this work.

List of Principal Equipment—High-Pressure Extension at L Street Station

TURBINE-GENERATOR 20,000 kw, 37,500 kva; steam conditions, 1200 lb, 910 F, to 300–200 lb	*Westinghouse Electric & Mfg. Company*
BOILERS Two of 375,000 lb per hr capacity; 1200 lb pressure, 910 F total steam temperature	*Combustion Engineering Company, Inc.*
INDUCED-DRAFT FANS Two 1000-hp variable speed	*B. F. Sturtevant Company*
HYDRAULIC COUPLINGS, two	*American Blower Corporation*
FORCED-DRAFT FANS Two 300-hp vane control	*B. F. Sturtevant Company*
PULVERIZERS Four Raymond bowl mills	*Combustion Engineering Company, Inc.*
BOILER FEED PUMPS Four 1250-hp, 400,000 lb per hr	*Ingersoll-Rand Company*
DUST CATCHERS Two Cottrell precipitators	*Research Corporation*
DEAERATORS Two 400,000 lb per hr, 55 lb, 300 F	*Worthington Pump and Machinery Corp.*
ASH-HANDLING SYSTEM Completely pneumatic	*United Conveyor Corporation*
BOILER CONTROL	*Bailey Meter Company*
SUPERHEAT CONTROL	*Leeds & Northrup Company*
BOILER FEED PUMP CONTROL	*Republic Flow Meters Company*
DESUPERHEATING AND PRESSURE-REDUCING EQUIPMENT	*Republic Flow Meters Company*
LARGE MOTORS For boiler-feed pumps, fans, pulverizers, etc.	*General Electric Company*
TURBINES For driving boiler feed pumps—1350 hp.	*Moore Steam Turbine Company*

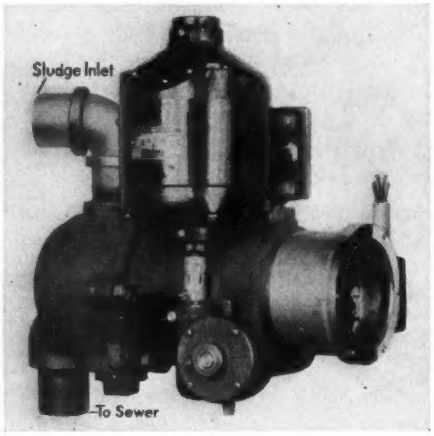
New A. S. T. M. Standard for Boiler Tubes

Among several new standards lately approved by the A. S. T. M. is one involving particularly the field of pipe, boiler tubes and tubing materials. One noteworthy change was to issue revisions in the form of new tentative specifications to replace immediately the standard covering lap-welded and seamless steel and lap-welded iron boiler tubes (A 83–36). The new tentative specification (A83–37T) is especially significant because the committee has recognized the advantages of designating wall thicknesses by decimals in place of Bwg and fractions, as well as the desirability of indicating permissible variations for wall thickness and weight in percentages rather than by the existing dual system. The former grade of medium carbon material in the specification was deleted and a new tentative specification for medium carbon seamless steel boiler tubes was approved.

NEW EQUIPMENT

Desludging Valve

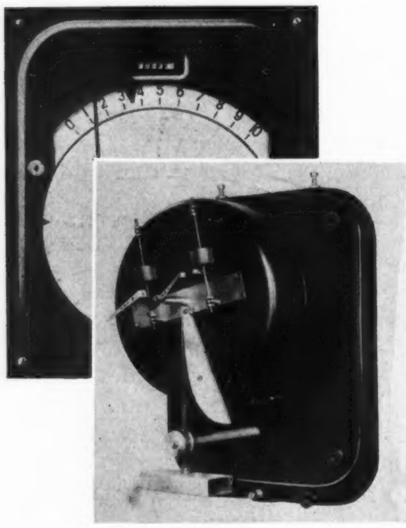
A new automatic desludging valve has been developed by the Permutit Company as a part of its hot-process lime-soda water softener in which sludge must periodically be removed from a settling tank. The new desludging valve permits the flow of sludge from a container by gravity or under pressure. Automatic operation of such a valve is highly desirable because



periodic desludging by hand is apt to be overlooked or postponed for such an interval as to impair the efficiency of operation. With automatic desludging this is accomplished under precise control, thus assuring uniform conditions. The valve, as here shown, is motor-operated and of simple construction.

Gas Flow Meter

The illustration shows the new Cochrane ring-balance flow meter for low-pressure gas measurement. This instrument is designed for operating differentials as low as 2 in. of water and is applicable to measurement of gases at pressures below those for



which the customary types of mercury-sealed flow meters are suitable.

The meter consists of a ring-shaped hollow body, rotably supported on knife edges at its center, so as to be capable of turning freely. The annular body is partly filled with water, oil or an anti-freeze liquid, and is divided at the top by a partition wall, to each side of which a flexible tube is led for the purpose of subjecting the unit to the differential pressure from an orifice or flow nozzle through which flow is to be measured. When flow occurs through the orifice plate, the resultant differential pressure causes the liquid in the ring balance to be transferred from one side to the other, whereupon the ring balance rotates to a new position of equilibrium. Motion is maintained proportional to flow by a suspended weight and cam.

It is characterized by high operating power for low-pressure gas measurement, charts and indicator scale graduated uniformly in terms of flow, a calibrating weight by means of which the accuracy may be checked quickly, direct-reading integrator and guaranteed accuracy.

Mechanical Oil Burner

A new variable capacity mechanical atomizing oil burner has been brought out by Todd Combustion Equipment, Inc. Among its special features are unlimited firing range without change of burner tips, change in oil delivery pressure, or change in angle of spray, and automatic control. It operates at 300 lb working pressure.

Because of the automatic control and the fact that its capacity curve is a straight line rather than a square-root curve, and that the air-flow curve is also a straight line, a constant ratio of fuel-to-air is maintained throughout the entire range of boiler operation, thus maintaining maximum CO_2.

New Nickel Alloy

A new alloy, containing 98 per cent nickel and designated as "Z" Nickel, has been brought out by The International Nickel Company after six years of laboratory and field study. It has been produced with a tensile strength as high as 250,000 lb per sq in. and a hardness of 46 Rockwell C. In its unhardened or annealed condition it fabricates almost as easily as pure nickel. The metal can be heat-treated after fabrication with little if any distortion since heat treating is carried out at relatively low temperatures, usually 890 to 930 F for from six to sixteen hours. Quenching from 2000 F is necessary to render "Z" Nickel susceptible to heat treatment.

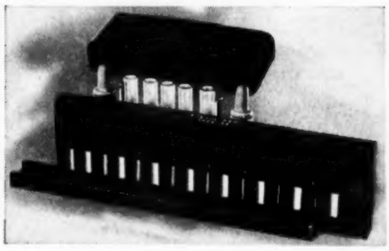
The commercial production of "Z" Nickel is too recent to indicate the range of its possible applications, but it has already been used for hand tools, spring coils, wire brushes and a variety of electrical applications. It is produced as hot rolled or cold rolled strip in a wide range of sizes and in various tempers.

pH Slide Comparator

A new Slide Comparator for the colorimetric determination of pH, chlorine and phosphates has been developed by W. A. Taylor & Co., Baltimore. The outfit is molded entirely from plastic, radical changes in design having resulted in improved appearance, durability and ease of handling; also the weight has been reduced to $1^1/_2$ lb. Its dimensions are $10 \times 4 \times 2^1/_8$ in. All pH, chlorine and phosphate values, as well as the indicator names, are engraved in white directly on the plastic slides.

The new Comparator consists of a slide and a base. Each slide contains nine color standards alternating with ampoules of distilled water. All color standards are guaranteed by the manufacturer to maintain their accuracy for a period of 5 years. The base contains two vials of indicator solution, with 0.5 cc pipettes, 5-5 cc test tubes and a piece of etched glass in a special compartment.

Determinations are made by filling three of the test tubes with the test sample,



adding 0.5 cc of indicator solution to the middle one, placing the slide on the base and moving it back and forth until the test sample matches one of the color standards. The pH, chlorine or phosphate value is then read off directly from the values on the slide. One base can be used with any number of color standard slides.

2500-Lb Safety Valve

The Consolidated Safety Valve Division of Manning, Maxwell & Moore, Inc., annouces the completion of a new line of safety valves for elevated pressures and temperatures up to 2500 lb at 1000 F. These new valves are to be installed on the highest pressure commercial steam boiler ever built in this country.

Special alloy steels with low coefficients of expansion have been selected for the bodies, bonnets, springs and trim so that these valves will provide the same safety performance at this new high in operating conditions that is regularly produced in safety valves for 300-lb boilers. Bodies and bonnets are assembled with through bolts to prevent "freezing" at high temperatures. The trim is treated stainless steel. Constant seat diameter is insured by a new type of bevel seat in which the actual contact bearing between the seat and disk is always at the lowest portion of the seat surface. The single ring type of blow-down control is used.

Relation of Characteristics of Bituminous Coals to Their Use in Pulverized Firing

This survey, undertaken by Bituminous Coal Research, Inc., was conducted through interviews with purchasing agents and engineers at forty-three plants in Ohio, Pennsylvania, New York and Michigan where pulverized coal is fired. Data were obtained on the effect of coal size and moisture upon the storage, handling, pulverizing and combustion of bituminous coal; also ash-softening temperature and oil treatment. The preferences of the users for the various sizes of coal on the market have also been obtained and classified.

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DURING recent years the coal industry has experienced several changes in the demand for the sizes of coal that are used in mechanical firing. More accurate screen sizing, double-screening and greater uniformity of size distribution in the coal sold to any group of customers have become the order of the day. With these changes have come additional problems in marketing. For example, in a certain high-volatile field, the production of 100 carloads of $^3/_8 \times 1^1/_4$-in. coal for residential stokers results in the production of approximately 83 carloads of $0 \times {}^3/_8$-in. coal, a market for which must be found during the same seasons.

Plants in which coal is fired in pulverized form have a selection from a wider range of sizes than heretofore. They are naturally interested in taking full advantage of what the coal industry has to offer. Despite the fact that all of the coal they receive must be pulverized to the same small size before burning, regardless of its original size, the initial size range of particles has an effect upon the degree of satisfaction experienced at the plant.

A survey of industrial and utility plants at which coal is fired in pulverized form was undertaken to determine the present trends in coal selection and the effects of the size and moisture content of coal upon the handling problems and upon the pulverizer capacity and power requirements. Comments and suggestions were solicited on any and all phases of the problem of firing a furnace with pulverized coal.

Plants Included in Survey

The survey was confined to the industrial centers of Ohio, Pennsylvania, New York and Michigan because coals from a larger range of seams could be included with less traveling time in this area than by going elsewhere. The data were obtained from the purchasing agents, engineers and firemen of forty-three plants in seventeen cities. With the exception of one cement kiln, each plant used the coal to generate steam. A total of 5,143,000 tons of coal was used in 1937 at the plants surveyed.

Of these plants, twenty-six used coal above 30 per cent in volatile content (high volatile), eleven burned coal with less than 30 per cent volatile matter (medium and low-volatile) and six plants used both. The coal burned in these plants came from as far south as the Appalachian, New River and Pocahontas fields. Appreciable tonnages came from the Pittsburgh seam and from the medium-volatile area in Pennsylvania. A large part of the coal used in the Ohio plants came from the Ohio mines.

The coal was received by truck at five plants, by barge or boat at eight, and by rail at thirty.

Table I shows the numbers and percentages of the plants included in several brackets of annual tonnage used. Both large and small users were canvassed; the greatest number was in the class using from 10,000 to 50,000 tons per year or about one to five cars of coal per day.

TABLE I—SIZE OF PLANTS SURVEYED

Size of Plant in Tonnage of Coal Used per Year	Number of Plants	Percentage of Plants
Over 300,000 tons per year	8	18
100,000 to 300,000	6	14
50,000 to 100,000	7	16
10,000 to 50,000	15	35
5,000 to 10,000	5	12
Less than 5,000	2	5
	43	100

This report is limited entirely to technical features and purposely does not discuss questions regarding the selection of coal by size because of any economic factors. It is obvious, however, that the selection of coal sizes is made by the user with a consideration of price as well as the technical features. The most common practice, where proper evaluations are made, is to base the selection upon a comparison of the fuel cost per 1000 lb of steam generated for those coals that could be handled and burned without serious difficulties. In that way both performance and cost of the coal influenced the selection. The chief engineers knew both the technical and economic factors affecting their plants and did not normally consider one without the other.

In a measure, most technical factors are influenced by the relative prices of various coals. For example, difficulties with wet coal that would reduce the steaming capacity of an installation would be removed by a change in the equipment design if the price differentials in favor of the wet coal were large enough.

The survey shows both the state of the art at the present time in the territory covered and the effect of several factors upon the use of coal. It is recognized that differences in the characteristics of high-, medium- and low-volatile coals render it impossible to make general statements applicable to all coals.

Attitudes of Consumers toward Coal Sizes

Table II shows the number of plants using and preferring the several sizes of coal. These do not total to forty-three plants because some employed several sizes or preferred several sizes equally well. The degree of satisfaction with the size of coal in use can be appreciated from the fact that only six plants reported they did not include one or more of the sizes of coal in use among those preferred. The engineers at seven plants had no preferences on coal size except that the top size should not exceed $1^1/_2$ in.

TABLE II—COAL SIZES USED AND PREFERRED

Nominal Size of Coal As Received at Plant	Number of Plants Who Use It	Prefer It
Run of Mine	1	2
0×2 in.	5	1
$0 \times 1^1/_2$ and $0 \times 1^1/_4$ in.	11	12
0×1 and $0 \times {}^3/_4$ in.	20	15
$0 \times {}^5/_8$ in.	14	11
$0 \times {}^1/_2$ in.	11	12
$0 \times {}^3/_8$ in.	13	15
$0 \times {}^1/_4$ in.	3	3

As indicated, the size of coal now used and preferred in most of the plants surveyed is a $0 \times {}^3/_4$ or 0×1-in. coal. No distinction was made on merit between these sizes by the users.

Table III is an analysis of the attitudes of the consumers toward the $0 \times {}^3/_4$-in. size. Sixty per cent of the plants either use this size or prefer it to those now used. One-fourth of the users interviewed are prospects for this size because they are favorably inclined to try it.

TABLE III—ATTITUDES OF CONSUMERS TOWARD $0 \times 3/4$- and 0×1-IN. COAL. HIGH, MEDIUM AND LOW VOLATILE

Consumers of Coal for Pulverized Firing	Number of Plants	Percentage of Plants	Percentage of Tonnage Represented	Tons per Year
Those who use this size coal at least part of the time	23	53	61	3,159,170
Of the balance, those who prefer this size coal and could use it satisfactorily, but are not using it	3	7	9	465,000
Those who would use this size coal if it were treated to allay dust by oil, moisture or both	0	0	0	0
Those who would use this size coal if it had a lower ash or moisture content than those now available to them	0	0	0	0
Those who have never tried coal with these top sizes but are favorably inclined to do so	11	26	27	1,386,528
Those who cannot use or will not use these sizes	6	14	3	132,290
Total	43	100	100	5,142,988

Table IV shows a similar analysis of attitudes toward the $0 \times {}^3/_4$-in. coal. Objections to this coal at several plants, other than the size itself, were the lack of dust treatment, excess moisture or excess ash content. Coals without these objections were, however, generally available to each market area.

TABLE IV—ATTITUDE OF CONSUMERS TOWARD $0 \times {}^3/_8$-IN. COAL. HIGH, MEDIUM AND LOW VOLATILE

Position to Coal Trade	Consumers of Coal for Pulverized Firing	Number of Plants	Percentage of Plants	Percentage of Tonnage Represented	Tonnage per Year
Present Users	Those who use $0 \times {}^3/_8$-in. coal at least part of the time	16	37	47	2,439,915
Would-be Users	Of the balance, those who prefer $0 \times {}^3/_8$-in. coal and could use it satisfactorily, but are not using it	7	16	4	206,693
Prospects for an Improved Product	Those who would use $0 \times {}^3/_8$-in. or smaller coal if it were treated to allay dust by oil, moisture, or both	3	7	14	695,000
	Those who would use a $0 \times {}^3/_8$-in. coal which has a lower ash content or a lower moisture content than those now available to them	2	5	nil	10,380
Prospects	Those who have never tried coal with a top size of less than $0 \times {}^5/_8$ in. but are inclined favorably to try $0 \times {}^3/_8$-in. coal	6	14	11	555,500
Cannot Use $0 \times {}^3/_8$-In. Coal	Those who probably would not be prospects for $0 \times {}^3/_8$-in. coal or have used it and did not find it satisfactory for their purpose	9	21	24	1,233,500
	Total	43	100	100	5,140,988

A further breakdown of these data by volatile contents did not indicate a difference in the attitudes shown in Tables III and IV for those who used high volatile coal from those using low or medium volatile coal. Twenty-one per cent of the plants did not find the $0 \times {}^3/_8$-in. coal satisfactory for their use for the individual reasons given in Table V.

TABLE V—REASONS WHY $0 \times {}^3/_8$-IN. COAL COULD NOT BE USED

Reasons	Number of Plants
1. Bunker system was such that they could not keep pulverized coal separate from stoker coal and therefore bought a size suitable for stokers	2
2. Coal hoisted with clam-buckets. Loss and dust with small coal was prohibitive	1
3. Want still smaller coal ($0 \times {}^1/_4$ in.) to get necessary grinding capacity	1
4. "Small coal makes mills rumble"	1
5. $0 \times {}^3/_8$-in. coal *reduced* mill capacity with obsolete make of mills	2
6. Would need extra men to unload $0 \times {}^3/_8$-in. coal if moist enough to allay dust as desired	2
Total	9

Technical Factors Affecting Use—Unloading of Coal

Where coal was received by boats or barges that drew up to the dock beside the steam plant, the cargo was unloaded by clam-buckets that raised the coal from the holds and deposited it on storage piles. Some loss of coal into the water and a dust nuisance occurred when the coal was as small as $0 \times {}^3/_8$ in., because the clam-bucket jaws did not close tightly enough to prevent leakage of the small material. That experience did not apply generally where clam-buckets were used, because at some plants a reasonable amount of maintenance kept the jaws fitting tightly enough to prevent a dust nuisance or coal loss. The height of lift and wind velocities also affected the losses.

Thirty plants received coal by rail in hopper-bottom cars. Rotary car dumpers were used for unloading the coal at two stations, but the others discharged all or part of each car directly into a track hopper. In the latter case a clam-bucket was used at several places to remove coal from the cars and place it in storage, but the car was cleaned into the track hopper. With normal weather during transit, coal with a top size of over 2 in. would flow out of the cars with little atten-

tion after the hopper doors were opened. When the top size was below 2 in., however, it was necessary for a man to enter the car to push down part of the coal and finish the unloading with a broom or shovel.

During periods of normal weather, the coal may have been subjected to as much as an inch of rainfall while in transit from the mines to the plants, and a small part of this moisture was sometimes dried off the car during the balance of the haul. The amount of moisture present may not have been enough to allay all of the dust, but, because of the short fall into the track hoppers, the dust caused little or no nuisance. Approximately 4 per cent moisture in the eastern coals was sufficient to allay practically all of the dust.

During periods of heavier rainfall, the penetration of the water into the carload of coal varied both with the original moisture content and the amount of rainfall. Coal that was moist on loading permitted more complete and rapid penetration than drier coal. The top layer of coal tended to shed water to the side of the car where the water would flow downward and drain out.

When the car bottoms were opened under a wet shipment, only a small portion of the carload would fall out. To a lesser degree, the same type of bridging occurred with the drier small coal. A few raps on the sides of the cars with malls or small sledges broke the arches of coal and caused most of the coal to flow freely. After free flow had ceased, coal handlers climbed into the cars and pushed the remainder of the coal down the slopes of the car bottoms. Almost invariably a man had to enter the car to complete the unloading except, of course, where rotary car dumpers were used.

Although the flow of coal was quite different in the smaller sizes than in the larger ones, the difference between the handling properties was not generally significant in plant operation where unloading was assigned to helpers as a part-time routine and usually represented only a minor item of attention and cost.

Storage of Coal

After unloading, the coal was either placed in outdoor, seldom indoor, storage or lifted to the overhead bunkers inside the boiler house. Coal that was placed in storage out of doors generally became damp or wet during the fall, winter and spring seasons. Although subjected to snow and freezing weather during the winter, coal in storage usually heated sufficiently by spontaneous oxidation to counteract the effect of freezing weather except at the edges of the piles. Coals to be stored for six months or longer were generally selected from those having a sulphur content of 1.5 per cent or less, because plant operators considered the sulphur content to be not only the best index but the principal cause of spontaneous heating and firing.

The users favored the larger sizes of nut slacks and even run-of-mine for storage purposes, because that coal was believed to store with less likelihood of spontaneous ignition. Coals that were purchased especially for storage were kept there longer than when the normal shipments were stored.

Coal Handling in the Plant

Many plants were equipped with crushers or breakers to reduce the coal to one inch or less prior to elevating it to the bunkers. On discharging into the bunkers, the coal fell into conical piles and was allowed to flow freely. The segregation of the sizes that occurred did not interfere with the feeding or pulverizing but required small changes in the setting of the feeder gate at the pulverizer. Such adjustments were made automatically when feed settings were changed for general load changes. The coal segregated less as the moisture content increased.

As needed, coal was drawn by gravity from the bottoms of the bunkers. Automatic weighing machines which discharged increments of 200 lb of coal into the small closed hoppers and feed pipes below were used at a number of the plants. The feed pipes led to the mill feeders which were usually attached directly to the mills.

In so far as possible, the downcomers were made vertical, but in some plants design conditions prevented this arrangement. For various reasons coal bunkers were often designed with a greater ratio of width to height than desirable for free flow of coal, thereby leaving large masses of fuel in dead storage.

Wet coal of 0 × 1 in. or less had an angle of repose approaching 90 deg. Small, wet coal occasionally clogged feed pipes and entrances to feeders that were not properly designed. Table VI presents the responses to questions on that subject.

TABLE VI—DIFFICULTIES WITH WET COAL

Difficulty	No. of Plants
Wet coal does not flow freely from bunkers—rat holing, high angle of repose	15
Occasional clogging of downcomers (feed pipes) from the bunkers and scales when using wet coal	9
Occasional clogging of pipes or small hopper at automatic scale with wet coal	3
Occasional clogging of mill feeder with wet coal	6
Clogging of discharge pipe from mill when using wet coal	2
Total	35

The plant total in this does not indicate that 35 of the 43 had those difficulties. Some of the plants experienced several of the types stated.

The purpose in pointing out these details is to explain the problems that each plant faces in the handling of coal, but to appreciate fully the extent of the difficulties with sticking and clogging, one must remember that coal wet enough to cause these difficulties was received but a small part of the time at the average plant. Even then, while wet coal was being used, stoppage occurred only occasionally, and only rarely did it cause loss of ignition.

Plant engineers and firemen are an ingenious group of practical men who handle situations every day that would otherwise cause a shutdown in short time except for their simple remedies. Maintaining a flow of coal to the pulverizer is one of the least of their problems.

Pulverization

With two exceptions, the engineers interviewed noted so little effect of coal size upon performance of the mills that no significant advantage or disadvantage could be attached to any particular size of coal. The operators who favored the smaller sizes of coal believed it to be a common-sense policy to relieve the mills of as much work as possible by using a small size of coal. The data obtained from the mill manufacturers indicated an increase in mill capacity of between 10 and 15 per cent on reduction of the initial top size of the slack from 2 in. to $^3/_8$ in. Some manufacturers of pulverizing equipment are now focusing attention on standardizing their machines on a 0 × $^3/_4$-in. coal. The top size of coal to be handled in the feeders was generally limited to about 2 in.

Depending upon the rapidity with which surface moisture was evaporated from the coal during pulverization, the mills may or may not have suffered a loss of capacity with increasing moisture content. Where the mills had a high enough inlet air temperature to maintain a temperature of 130 F in the mixture of coal and air leaving the mill, even wet coal reduced the mill capacity little below that with the same coal dried to 2 per cent moisture.

The temperature of the air that swept through the mills was not always high enough at seventeen plants, but was ample in the other twenty-six plants. Three of the units had no air preheat. Only one unit pulverized coal previously dried outside of the mill. Six of the plants, where the bin system of handling pulverized coal was used, recirculated between 75 and 90 per cent of the air used to sweep the mills. The air became very nearly saturated with moisture and, hence, had very little drying capacity.

An inlet air temperature of approximately 265 F is necessary to reduce the moisture content of a coal from 8 per cent to 2 per cent if 15 per cent of the air for combustion is used to sweep the mill.

Because of the extensive discussions of grindability of coal that have appeared in the literature, an attempt was made to obtain the experiences of the plant operators with that factor. The comments indicate that although mill manufacturers and plant designers may be vitally concerned with the effect of grindability, if a mill of ample size has been installed, the differences in grindability between coals ceased to be a problem. Judging by the data taken on the survey, the subject of grindability of coal has received entirely too much emphasis in the sale and purchase of coal.

The operators recognized that high-volatile coal ignited more readily and burned more rapidly than low-volatile coal pulverized to the same size and also that the low-volatile coal should be pulverized more finely than high-volatile coal for equal rapidity of burning.

The fineness of pulverization was determined by a sieving analysis at a few of the plants but the common method of determining whether or not the degree of pulverization was satisfactory was by watching for "sparklers" of burning coal in the furnace. The operators considered the percentage of the coal that passed through a 200-mesh sieve as less important than that no more than one per cent should remain on a 50-mesh sieve. When sparklers appeared, the pressure between the grinding elements was increased or worn mill parts were replaced, depending upon the type and condition of the particular mill.

Furnace Performance

The initial moisture in the coal supplied to the pulverizer may have been evaporated almost completely from the coal, but the moisture, as water vapor, entered the burners and furnaces with the coal. Excessive water vapor present with the primary air caused a noticeable delay in ignition and a tendency for the flame to puff or pulsate. Black streaks of coal, which varied in length with the pulsations, could be seen around the outside of the base of the flame.

Every pound of moisture that entered the furnace passed out of the boiler setting carrying away heat that would otherwise have been delivered to the boiler. This loss was not especially serious, even with wet coal, but in the last analysis additional coal was burned to offset the heat loss due to the moisture in the coal.

Unfortunately, many boiler furnaces were so constructed that the fuel selection was limited to those coals that had an ash-fusion temperature of 2500 F or over. The plant engineers complained about that limitation of their equipment because it caused them trouble with coals that were occasionally received and because it limited the selection of the coals.

At a few of the plants the boiler furnaces were operated without ash removal until an accumulation of ash several feet deep had taken place. The units were then shut down, allowed to cool for several days, and then cleaned with hoes, picks and shovels. The fusion temperature of the ash for such operation must be high enough to prevent the formation of a pool of slag, because the frozen slag cannot be removed from dry-bottom furnaces except with difficulty and with injury to the furnace floor.

Table VII presents a list of the number of plants using coals with ash-softening temperatures from under 2200 F to over 2800 F, according to temperature groupings.

TABLE VII—ASH FUSION TEMPERATURES OF COALS USED IN PLANTS SURVEYED

Fusion Temperature		Number of Plants	Annual Tonnage
Less than 2200 F	21 plants	6	1,947,000
2200 to 2300 F		11	665,050
2300 to 2400 F		4	782,163
2400 to 2500 F*	22 plants	6	362,000
2500 to 2600 F**		5	1,138,125
2600 to 2700 F		6	157,650
2700 to 2800 F		2	50,000
Over 2800 F		3	41,000
		43	5,142,988

* Maximum for two plants with slagging furnaces.
** Maximum for one plant with slagging furnaces.

With the exception of the three plants with slagging furnaces, high ash fusion temperatures were, of course, preferred. In slagging furnaces, the viscosity of the slag appears to be of as great importance as the softening temperature.

Other Comments

Six of the forty-three plants were receiving $0 \times {}^1/_4$-in. to $0 \times {}^3/_4$-in. coal treated with oil to the extent of from 3 quarts to $1^1/_2$ gal per ton. Those who were using oiled coal believed that the oil not only reduced the dust normally given off, but also reduced the penetration of rainfall into the coal in transit, prevented windage losses from the car and caused the coal to flow freely in the plant. Comments received at other plants were to the effect that oiled coal did not flow as freely in bunkers and pipes as untreated coal, especially when high in moisture content; the amount of oil used did not allay dust sufficiently; oiled coal was not offered to them, and some believed that the oil might deteriorate rubber conveyor belts.

Complaints voiced during the interviews with regard to tramp iron, wood, straw, rags and paper in the coal indicated a need for more care by the producers and shippers in keeping extraneous material out of the shipments. Except for tramp iron and a portion of the wood, the materials were originally used to seal the hopper doors on the railroad cars and therefore entered the coal when the hoppers were opened. A material should be used that will break up readily at the plant. A mixture of fine coal, fire clay and water has been successfully used to seal the car hopper doors. The use of magnetic sepa-

rators at the mine tipples would recover most of the iron, part of which could again be used in the mines.

Coal Selection for Pulverized Firing

The significant feature of a pulverizer unit from the standpoint of coal selection is the responsiveness of the unit to important differences between coals and the ease with which a plant operator can see and interpret them.

The effects of coal size and moisture content are known almost immediately after the coal enters the mills. The mill feeder can be quickly adjusted for the coal and coal size to conform with the steam load. The preheated air and tempering air can readily be adjusted to maintain a standardized mill outlet temperature.

Whether or not ignition at the burner is satisfactory is known immediately after the coal reaches the burner. The fineness of pulverization is checked by observation into the furnace for sparklers of burning coal. The first evidence of slagging of the boiler tubes, water walls or furnace floor indicate that the ash fusion temperature may not be suitable. If necessary, the amount of secondary air can be increased to reduce the furnace temperatures until the test coal can be burned out. Slagging of the tubes may also be prevented in some cases by shortening the length of flame travel.

The evaporation can be noted for any period of time from the steam charts and these in turn compared with the weight of coal passed through the automatic scales in the same time. More accurate checks on the performance of the coal and unit can be made by a standard boiler test.

The plant engineers were interested in the proximate analyses, calorific values and ash-softening temperatures of the coals used or offered. Records were kept of the evaporation obtained with the coals used. The procedures followed in most plants in evaluating a coal were essentially correct, logical and free from prejudice or bias.

Conclusions

1. Coals of all sizes between run-of-mine and $0 \times {}^1/_4$ in. were received at plants for firing in pulverized form. The $0 \times {}^3/_4$-in. size was most universally used and preferred. Sixty per cent of the installations surveyed either used or preferred this size.

2. The trend in size of coal selected for pulverized firing is heading distinctly toward the smaller sizes, as these become more available on the market.

3. Only 21 per cent of the plants could not, for various individual reasons, use a $0 \times {}^3/_8$-in. coal satisfactorily. Over 50 per cent of the plants were either using a $0 \times {}^3/_8$-in. coal at least part of the time or preferred that size.

4. Customers are generally well pleased with $0 \times {}^3/_4$-in. and $0 \times {}^3/_8$-in. coal, especially when the moisture content at the time of receipt is approximately 4 per cent. Up to this amount, the moisture content in the coal improved its handling qualities at the plants by practically eliminating the dust nuisance without significant interference with the flowing properties. When the moisture content was over 4 per cent, the effort and attention necessary to unload the coal and to insure a continuous supply at the pulverizer at all times, increased with increase in moisture.

5. Wet coal, although received only a small fraction of the time, caused a significant loss of milling capacity at 40 per cent of the installations because the temperatures of the air entering the mills were too low. Ample pulverizer capacity was available at 95 per cent of the plants visited.

6. Oil-treated coal was used in so few plants that conclusive data on its properties are lacking. Dusty coal was considered to be too dry rather than to be lacking a special dustless treatment.

7. The differences in pulverizer maintenance, capacity and power requirements because of variations in coal size and grindability were too small to influence justifiably the choice of coal except in cases of limitations in pulverizer capacity.

Ohio State Offers New Welding Course

A new curriculum in Ohio State University's college of engineering leading to a degree in welding engineering has recently been established.

Administration of the course will be under the department of industrial engineering which for a number of years has presented the shop courses in welding required by various curricula in the engineering college. Entrance requirements are the same as for the other curricula of the college of engineering. Welding engineering students will take the same work as other engineering students the first year. For succeeding years they will have courses in calculus, physics, mechanics, metallurgy, economics and accounting, drawing, English, welding applications and work in electrical, civil, industrial and mechanical engineering, as well as military science.

Commenting on the new course, Dean C. E. MacQuigg observes that, "Because of the rapid growth of the art and the very special techniques involved, there has been little opportunity for the design practices to become rationalized. Until lately the operations have been largely empirical. In view of the quite involved relationships between the nature of the metal to be welded, the design of the joint, the practice used in manipulation of the torch or electrode, the nature of the filler metal, the heat treatment effects and other important factors, the routine production of welds has become a highly specialized practice in every aspect."

Horace P. Liversidge, formerly vice president and general manager of the Philadelphia Electric Company has been elected president of that company, succeeding W. H. Taylor who becomes chairman of the board of directors.

Clayton S. Coggeshall has been appointed manager of the turbine division, central station department of the General Electric Company, succeeding the late R. B. Beale. For some time Mr. Coggeshall served as general assistant to Mr. Beale and prior to that was manager of turbine sales at the Lynn Works.

Theodore Maynz has lately resumed his consulting engineering practice in steam power plant work and opened an office at 270 Madison Ave., New York.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

A New Drumless Boiler

The Schmidt'sche Heissdampf-Gesellschaft (Germany) has developed a drumless high-pressure boiler which operates with natural circulation and employs a novel method of removing the steam by taking advantage of the steam's separating from the water in nearly horizontal tubes. This is described by Dr.-Ing. E. L. Otto H. Hartmann in *Wärmewirtschaft* of September 1938.

Fig. 1 is a cross-section through the steam separator used in the experimental boiler and Fig. 2 shows a cross-section of the boiler itself which has a capacity of 4410 lb per hr at 924 lb per sq in. pressure.

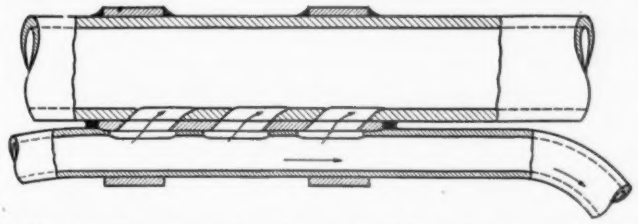

Fig. 1—The steam is skimmed off into the upper tube

Referring to Fig. 1 the mixture of steam and water, depending upon the operating pressure, has a velocity in the upper steaming portion of a tube of about 8 to 10 ft per sec. The steam is there skimmed off into a circular collecting header of relatively small cross-sectional area and the water flows on without being disturbed in the same direction to the entrance of the steaming tube. Each tube group has an independent circuit for the water so that interferences with circulation by adjoining tube circuits is thereby avoided. Separation is relatively complete since measurements show only $^1/_2$ to 1 per cent moisture in the steam. The quantity of water circulating varies from $2^1/_2$ to 3 times the quantity of steam made, or that in a once-through boiler. Tube cooling is considered sufficient when steam delivered to the point of separation from the water is in a saturated state, in which case the quantity of circulating water equals the quantity of steam made. It has been shown that proper cooling of the tubes depends, not so much on the velocity of the mixture as upon whether the tube wall is constantly kept wetted.

The design shown in Fig. 2 is intended for coal firing and has a revolving grate below a central coal magazine which has a storage of three to four hours boiler operating capacity. A pair of steaming tube groups encloses an annular furnace. On the outside there is a coil group made up of eight parallel coils[1] of 1.22 in. diameter and 60.7 ft in length and on the inside a similar group of three coils of like diameter. The steaming tubes are connected to a common feed-ring header at the bottom and to a steam-ring header at the top from which the steam flows to the superheater, also in the form of a ring-shaped coil.

Since the resistance within the steaming tubes is greater than that within the downcomers of equal diameter, the connection of the latter to the steaming tubes, which lie adjacent to the ring header connections from below, are provided with nozzles that have a low resistance in the direction of flow but a high resistance to circulation in the opposite direction. This avoids reversal of flow.

The furnace gases after leaving the superheater turn sharply over a soot hopper and pass upwardly through a ring-shaped economizer.

Air for combustion is drawn through the boiler casing on its way to the grate.

To one side of the boiler and at the height of the water level, there is a feedwater drum of about a foot in diameter and 2440 cu in. content. To this the feedwater is delivered from the economizer and from it the water flows into the common feed header.

The overall height of the outer coil group, from the center of the feed-ring header to the center of the steam-ring header is 56 in. The head for feeding water, taken by a water column connected into the middle of the bottom water ring, was $33^1/_2$ in. at maximum capacity. Before the feedwater is fed to the steaming section it is heated to steam temperature and degassed in the feedwater drum.

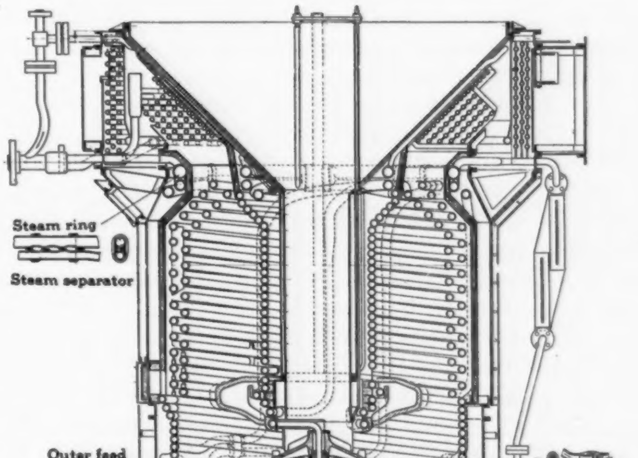

Fig. 2—Section through boiler and furnace

The entire water content of this boiler is slightly

[1] These are the first eight coils from the bottom, connected at different points to the feed-ring header (these connections and the downcomers being shown dotted). These same coils apparently spread out as they encircle the upper part of the furnace.—EDITOR

under 40 gal or about one-thirteenth of the hourly steam output.

Although no attempt has been made to reduce weight, the boiler including the bunker and grate weighs but little more than 8800 lb and is built so that it may be shipped as a unit.

A new method of regulation has been devised which, upon sudden stoppage of steam flow, at nearly full steam pressure, will prevent the safety valve from blowing. Full running conditions are reestablished in from 30 to 40 sec. A boiler efficiency of 78 per cent with a 608-F flue gas temperature has been attained with this experimental unit.

A design of this type of boiler for large capacity showed that only small steam collecting chambers are required although a larger number of tube coil groups becomes necessary. There is nothing to prevent tube coils up to 100 ft and more in length being used with natural circulation as greater boiler heights are employed.

The boiler has the same characteristics as two-drum vertical boilers and may therefore be fed with condensate of the same salt content. It may be blown down and can meet sudden fluctuations without priming. The salt content of the steam is lower than in the vertical boiler. Forced circulation may be adapted with this type of boiler if desired.

Power Plant of the "Queen Elizabeth"

The 85,000-ton liner *Queen Elizabeth* which was launched on September 27 for the Cunard-White Star Line will, when commissioned, be the largest merchant ship in the world. Among engineers, the first interest in such a vessel centers around the power plant and propulsive machinery. This is briefly described in the October issue of *The Shipbuilder and Marine-Engine Builder* (London), although it is anticipated that further details, particularly those concerning the boilers, will be available at a later date.

The ship will be driven by four main turbine sets each driving a propeller shaft through single-reduction gearing. Each set consists of a high-pressure, two intermediate-pressure and a low-pressure turbine, grouped around a common gear wheel. Astern turbines are incorporated in the casings of the second intermediate and the low-pressure turbines. The turbines will be supplied with steam at 425 lb pressure, 750 F total temperature by twelve oil-fired boilers of the Yarrow type placed in four boiler rooms. Incidentally, it will be recalled that the *Queen Mary*, which is only slightly smaller, has 24 main boilers operating at approximately the same pressure. At this writing no information has been given out as to the capacity of the *Queen Elizabeth's* boilers or as to the total rating of the main turbines, but assuming the total power to equal or slightly exceed that of the *Queen Mary*, which is 200,000 hp, the individual capacities of the boilers of the newer ship must be at least twice as large.

The internal surfaces of the boilers are to be Apexiorized and the soot blowers will operate with compressed air. All main steam lines will be of corrugated pipe to effect a saving in space, length of bends and consequent saving in weight.

Air for combustion will be supplied on the closed stokehold system by 12 sets of two Howden double-inlet motor-driven fans, and the flue gas will pass through vortex spray-type washers before discharging from the funnels.

Steam will be bled from the main turbines at 230 and 150 lb for feedwater heating, the low-pressure heaters being supplied with steam from the auxiliaries.

The electrical requirements of the ship will amount to 8800 kw, to be supplied by four 2200-kw d-c condensing turbine-generators. These will be divided between two separate power plants located on either side of a central watertight bulkhead between two of the main boiler rooms. Two 75-kw diesel sets are also installed for emergency service.

Guarding Boiler against Feed Interruptions

A device for guarding steam boilers against disturbances in the feedwater supply, as developed by Rheinmetall-Borsig, A.-G. is described by R. Reichardt in *Warmewirtschaft und Dampfkesselwesen*. Reference to the sketch will give an idea of how this emergency feed device functions.

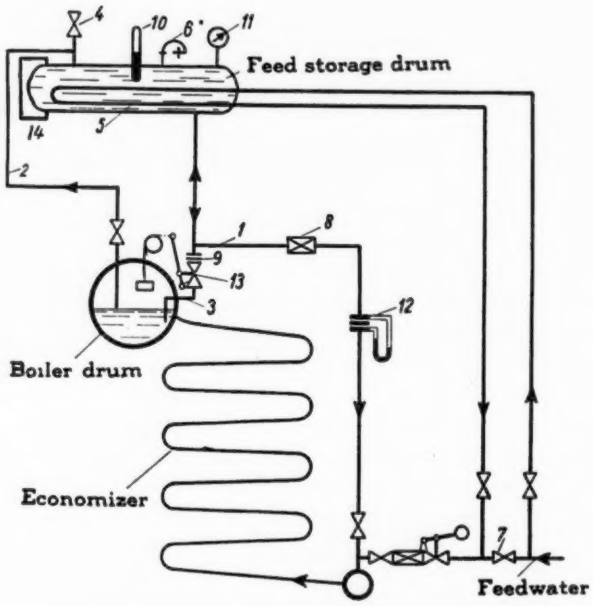

Diagram of emergency feed connections

The feed-storage drum, which is placed above the boiler drum, is connected therewith by a drain leading down to the economizer inlet header and by a steam pipe *2* leading from its top down into the boiler drum and ending at the lowest water level therein.

On starting, air is vented through valve *4* until the feed drum is filled with steam or water. As long as the lower end of pipe *2* is below the water level in the boiler the steam space in the feed drum is sealed at both ends and the steam therein condenses due to radiation from the drum to the surrounding air. This causes the feed drum to fill with boiler water through connections *2* and *3*. If the water level in the boiler drum falls below the end of pipe *2*, due to interruption of the feed, a connection is established between the steam spaces of the two drums

and water flows from the feed drum into the boiler until the bottom end of pipe *2* is again sealed by the rising water level. When the feedwater supply to the boiler is reestablished, the feed drum again fills up as before. Check valve *8* prevents short-circuiting the boiler feedwater past the economizer. To avoid flashing the water within the feed drums into steam, when the pressure falls therein, a cooling coil *5* is provided through which a controlled portion of the boiler feedwater is passed. Only a small portion of the water flowing from the feed drum is required for cooling the economizer which involves only a low loss of head (i. e., a relatively small distance between feed and boiler drums), and to maintain this low head a branch pipe *3* is provided to accommodate the remaining portion of water flowing from the feed drum to the boiler drum.

A regulator valve *13* serves as a guard against overfeeding the boiler drum which may occur when, upon a substantial pressure drop in the boiler causing a flashing into steam within the feed drum, this drum may drain completely. Valve *13* shuts off the flow of water through pipe *3* when the water level in the boiler rises too high. It is normally open and may stick and not function and to meet this situation an alarm *6* is provided. This consists of a float which actuates a signal when the water within the feed drum begins to empty out. An orifice *9* controls the rate of flow through pipe *3* so that the feed drum may empty within a predetermined time. A gage glass *14* indicates the water level.

As soon as the boiler feed is interrupted there is established a thermosyphonic circulation within a circuit that includes the boiler drum, feed drum and economizer, since the waterleg from the feed drum is heavier than that through the economizer. The economizer is then immediately protected.

Trends in British Power Plant Practice

Recent extensions to British central power stations are discussed in the October issue of *Engineering and Boiler House Review*. Although several of these installations have been reviewed from time to time in this department, the article cited gives a collective view of current activity and trends in British power circles, particularly with reference to pressures.

While pressures of about 600 lb per sq in. and total steam temperatures of 850 F appeared to be the generally accepted upper limit for several years, there have more recently been indications of acceptance of higher pressures and temperatures and a desire to try out certain continental designs employing forced circulation. This is apparent from the installation of Loeffler boilers at Brimsdown, a La Mont boiler at Deptford West Station and Velox boilers at Wellington, New Zealand; the last-named installation, while apart from England, nevertheless represents British practice. In addition to the foregoing, there is also on order for Battersea station a 550,000-lb per hr, 1420-lb pressure, 965-F natural-circulation boiler of the bent-tube type that will supply a topping turbine-generator exhausting to the present 600-lb plant.

This boiler is to be one of a pair which will eventually provide steam for a new 100,000-kw turbine-generator.

The high-pressure element of this turbine will be rated at 16,000 kw and will operate with a throttle pressure of 1350 lb, whereas the 84,000-kw low-pressure element will take steam either from the exhaust of the high-pressure turbine or the existing 600-lb station mains. The first high-pressure boiler, which is to be fired by an underfeed stoker will enable this new turbine-generator to produce 65 per cent of its maximum rating.

At Brimsdown two 210,000-lb per hr, 2000-lb pressure, 940-F Leoffler boilers have recently been put in service and two more for the same steam conditions but of 250,000 lb per hr capacity are on order. They are stoker fired.

The La Mont boiler at Deptford West is rated at 350,000 lb per hr and, although operating at only 385 lb pressure and 790 F, it is of the forced-circulation type. It will be fired by an underfeed stoker.

At the Kirkstall Station, Leeds, the new extension consists of three 230,000-lb per hr pulverized-coal-fired boilers designed for 490 lb pressure and 750 F total steam temperature.

At the Portsmouth Station an extension which went into service last July consists of two 150,000-lb per hr header-type boilers, fired by traveling-grate stokers and supplying steam to a 30,000-kw turbine-generator at 625 lb and 850 F.

The Kilmarnock Station, of the Ayrshire Electricity Board has been extended by the addition of a 30,000-kw turbine-generator supplied by two 150,000-lb per hr, 420-lb pressure, 800-F boilers fired by traveling-grate stokers.

A second extension now nearing completion at Ironbridge Station consists of five 270,000-lb per hr bent-tube boilers operating at 400 lb pressure and 800 F total steam temperature and fired by traveling-grate stokers. These will supply a third 50,000-kw turbine-generator. When completed the station will contain ten boilers of this capacity and four 50,000-kw turbine-generators.

Among other extensions authorized, some of which are now under construction, are three 350,000-lb per hr boilers for Hams Hall, three 187,500-lb per hr units for Blackburn Meadows, two 125,000-lb per hr units for Dunston and eight 135,000-lb hr units at Ferry Bridge Station, Yorkshire. Also, at the Stalybridge Station there are being installed three 150,000-lb per hr boilers to operate at 625 lb, 850 F, and both the Mercy Power Company and the Stockport Corporation are each installing three 150,000-lb per hr units, while two of similar size are going in Newport Station. Finally, at Barking "B" Station four new stoker-fired boilers of 256,000 lb per hr maximum capacity are being installed to supply a new 75,000-kw turbine-generator, making the fourth generating unit of this size in the plant.

In addition to the foregoing, two completely new power stations have been authorized, one at Little Barford, in Bedfordshire, and the other at Littlebrook. The former will contain, initially, three 300,000-lb per hr, 675-lb pressure, 910 F pulverized-coal-fired boilers and the latter will have six 256,000-lb per hr boilers, three stoker-fired and three fired with pulverized coal. They will furnish steam at 600 lb, 800 F to one 60,000-kw and two 30,000-kw turbine-generators.

Reviewing these installations, there appears to be no definite relation between the size of unit and the method of firing. The use of both economizers and air heaters is quite general as is also automatic combustion control.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Air Compressors

The Sullivan Machinery Company has released a new 20-page catalog describing and illustrating its Unitair stationary and semi-portable air compressors. A number of refinements and improvements have been made to this line of compact, two-stage, air-cooled compressors including the addition of a larger size (435 cu ft per min displacement), the use of force-feed lubrication and the design of a simplified automatic stop and start control for motor-driven styles. The bulletin fully describes these improvements and also covers power-unit-driven types.

Boiler Service Equipment

A new price list, Form L14D, applying to the boiler service equipment described in Bulletin 260-B14B, has just been issued by the turbine pump division of Roots-Connersville Blower Corporation. Prices are uniformly lower, and several new sizes have been included, which widens the range of application for which these units have been especially designed and built. These boiler service units cover three types of applications: condensate return for gravity systems, boiler makeup and condensate return and direct-feed boiler supply. All units are for use with open systems, and have vented tanks. They are suitable for boilers from $7^1/_2$ to 500 hp, or from 1000 to 68,000 sq ft of direct radiation, at pressures from 10 to 150 lb, with return-water temperature not exceeding 210 F.

Boiler Settings

A new 40-page edition of the catalog, "Plibrico Furnace Construction for H.R.T. Boilers," is offered by the Plibrico Jointless Firebrick Company. This book covers the subject of boiler setting construction and refractory linings for horizontal return-tubular and other types of fire tube boilers. A considerable section is devoted to air cooling, modernization of existing settings and principles of furnace design.

Chlorination

Wallace & Tiernan Products, Inc., has issued as a 38-page booklet the paper on "Chlorination of Condenser Cooling Water" by R. B. Martin which was presented at the last annual meeting of the A.S.M.E. This reviews the early experiments in the control of slime on condenser tubes and other low-temperature heat exchangers, also subsequent developments and recent refinements in such control by chlorination. The necessary equipment is described and illustrated and several alternate arrangements are shown. The results of certain biological studies are incorporated.

Economizers

Bulletin No. 167 of The Green Fuel Economizer Co., Inc., describes a cast-iron economizer having a special ringstay type of joint so designed as to withstand pressures up to 450 lb per sq in. This equipment is furnished with either horizontal or vertical tubes.

Feedwater Treatment

A new 16-page bulletin has been issued by the International Filter Company describing its "Infilco" hot-flow water softeners for boiler feedwater treatment. Chemical treatment in this softener is continuous and directly proportional to the flow of water at all times. Either dry or wet chemical feeders can be furnished, the latter having semi-cylindrical mixing tanks with vertical agitation for chemical mixing. While lime and soda-ash are ordinarily used, other chemicals may be employed as circumstances dictate. The system and apparatus are fully described and illustrated in the bulletin.

Instruments

A 64-page catalog entitled "TAG Indicating, Recording and Controlling Instruments for Temperature and Pressure" has just been published by C. J. Tagliabue Mfg. Co. In addition to the new line of recording thermometers and recording pressure gages with 10- and 12-in. charts, complete data will be found on indicating and recording controllers. The control instruments are listed in either the "on-off" model for all ordinary control applications, or the "throttling" model for use where any considerable apparatus lag is encountered. Many illustrations not only show how these pressure-spring instruments operate, but the practical installation photographs tell an interesting story of what they are doing for the process industries.

Pumps

Bulletin No. 210 lately issued by Goulds Pumps, Inc., covers a new line of single-stage centrifugal pumps in eighteen sizes from 5 to 1800 gpm against heads up to 110 ft. These are designed for either belt or motor drive. The bulletin contains tables of sizes and dimensions for different capacities and heads and describes in detail the design features of the pump.

Refractories

A 12-page booklet entitled "How to Reduce Spalling with Super Duty Refractories" has been published by the General Refractories Company. It is attractively printed in two colors and gives charts, tests and general information on three types of super-duty refractories.

Sewage Pumps

The designing of centrifugal pumps to handle liquids carrying solids in suspension, such as unscreened sewage and wood pulp in paper mills, was discussed by A. Peterson, Chief Engineer of the Pump Department of the De Laval Steam Turbine Co., in a paper presented last Fall before the American Society of Mechanical Engineers and is now reprinted in Bulletin E-1171 for general distribution. So-called non-clogging, or clogless, pumps are characterized by single suction impellers having large open passages without corners or surfaces upon which stringy materials or rags may hang up and accumulate. Ordinarily such impellers are of the enclosed type, as where the liquid carries grit; shrouded impellers retain their initial efficiency longer than do open impellers. The size of spheres that the impeller should be able to pass has been the subject of controversy, but ordinarily the ability to pass spheres up to within one or two inches of the diameter of the pump discharge nozzle is satisfactory, and in larger pumps three impeller vanes are preferable to two, as they guide the water better, resulting in higher efficiency. At low heads, even fairly small pumps should be run at slow speeds and the use of a speed reducing gear results in a cheaper and more efficient motor. A pump casing split at the plane of the shaft is recommended in the interest of accessibility.

Valves

A 48-page catalog, superseding all previous bulletins, has been issued by Homestead Valve Manufacturing Company. This describes its complete line of brass and semi-steel straightway valves for moderate pressures and steel valves for heavy duty; boiler blow-off valves for pressures up to 600 lb and remote control hydraulic operating valves for 1500 lb. Listed is also a triplex pump ranging in capacity from 15 to 120 gallons per hour. Numerous applications are illustrated and many dimensional tables are included.

Water Conditioning

D. W. Haering & Company, Inc., has a new 24-page catalog consisting of articles dealing with scale and corrosion control in various types of water-using systems. It is illustrated with photographs, charts diagrams and graphs and contains articles on, "Hot Water Conditioning," "Cooling Systems," "Heating Systems," "Internal Combustion Engines," "Chain Systems," "Why Proportion" and "Brine." The subject of scale and corrosion control is covered in clear concise language along with descriptions of corrective and control measures.

Fuel Engineering Conference

Engineers of the Kalamazoo valley region and Appalachian Coals, Inc., Cincinnati, O., have completed arrangements for another fuel engineering conference. This meeting, the twenty-fourth in a series of educational enterprises, is scheduled for Kalamazoo, Mich., on December 14 at the Columbia Hotel.

During the afternoon session four papers will discuss small power plants, underfeed stokers, stoker engineering and smoke abatement. Combustion of pulverized coal will be the main topic of discussion in the evening. The program is as follows:

"The Modern Small Power Plant" by H. L. Solberg, Purdue University.

"Combustion Practices and Experiences with Underfeed Stokers," by G. G. Zimmerman, test engineer, Indiana Service Corporation.

"Engineering in the Small Stoker Industry," by E. C. Webb.

"Some Fundamentals of Smoke Abatement," by J. F. Barkley, United States Bureau of Mines.

"Combustion of Pulverized Coal," by E. G. Bailey, Babcock & Wilcox Co.

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